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WILLARD ROUSE JILLSON
DIRECTOR AND STATE GEOLOGIST

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Glass Sands of Kentucky

1920

The GLASS SANDS *of* KENTUCKY

A Detailed Report Covering the Examination, Analysis and Industrial Evaluation of the Principal Glass Sand Deposits of the State

BY

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Illustrated with Twenty-three Photographs Maps and Designs

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LETTER *of* TRANSMISSION

Frankfort, Ky., Sept. 10, 1920.

Professor Willard Rouse Jillson,
Director and State Geologist,
The Kentucky Geological Survey,
Frankfort, Ky.

Dear Sir:

Permit me to transmit herewith my manuscript and illustrations of a report on the Glass Sands of Kentucky.

The field work for the preparation of this report was done during the present summer. The time at my disposal for this work has proven inadequate to cover the entire State. The most promising counties have been visited and their glass sand possibilities will be found described herein. As all the counties within the State have not been visited the report must be considered as one of progress, rather than a complete report upon all the glass sand possibilities of Kentucky.

It is hoped that the report will contribute somewhat to the literature of the country on the glass industry and prove of service not only to the people of the State of Kentucky, but also to prospective manufacturers everywhere who may be interested in the commercial development of glass sand deposits in this State.

Respectfully submitted,

CHARLES H. RICHARDSON,
Assistant Geologist.

Glass Sands of Kentucky

BY
CHARLES H. RICHARDSON

Introduction

The object of this report of progress upon the glass sands of Kentucky is mainly to present to the general public, thru libraries, boards of trade, chambers of commerce, unfamiliar with the glass sand resources of Kentucky, some information of general interest and value upon the glass sand possibilities of the State.

It seemed advisable to take up this problem of investigation because there was no classified literature published by the State Geological Survey upon this particular phase of Kentucky's mineral resources. Only isolated notes have appeared here and there in the various publications of the Geological Survey bearing upon the possibilities of the occurrence of glass sands in Kentucky.

In connection with the preparation of this report the writer visited sixty-six of the large glass factories in Pennsylvania and West Virginia to study the various methods utilized in the manufacture of all kinds of glass ware, the source and kinds of the materials used in the different factories and the types of their finished products.

The author of this report herewith expresses his sincere thanks to the management of all these factories for their unfailing courtesies, the privilege extended to him of studying every phase of the glass industry, and for the valuable contributions they have given to this publication.

Furthermore he expresses herewith his indebtedness to the Technical Library of Carnegie Institute of Technology, Pittsburg, Pa., for placing at his disposal a large list of publications relating to the technique of the manufacture of glass and the requisites of the numerous products that enter therein. Also the various libraries of West Virginia and Kentucky for kindred services rendered.

Especial indebtedness is recognized to Prof. Willard Rouse Jillson, State Geologist, for his many timely suggestions and hearty cooperation in this work; to Dr. Alfred M. Peter, of the Experiment Station, Lexington, Ky., for the chemical analysis of numerous sands and sandstones collected in the field work; to P. G. H. Boswell for his memoir on Sands Suitable for Glass Making; to Walter Rosenhain for his book on Glass Manufacture; to Charles R. Fettke, Assistant Professor in Geology and Mineralogy in the Carnegie Institute of Technology, Pittsburg, Pa., for his report on Glass Manufacture and the Glass Sand Industry of Pennsylvania; and to all others who have in any measure contributed to the interest and the economic value of this report.

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CHAPTER I.

FIELD WORK.

The field work upon which this report is based was done during the months of June, July and August, 1920. The most promising localities for the occurrence of unconsolidated river sands and outcrops of sandstones were visited. However, some very important deposits from an economic viewpoint may have been omitted. The time at the author's disposal was inadequate to cover all the possibilities of merchantable glass sands within the State.

The chief lines of investigation were conducted in the Olive Hill District in Carter and Rowan counties, between Morehead and Hitchins; in the Ashland-Catlettsburg District, Boyd county; in the Big Sandy District, Louisa, Lawrence county, Paintsville, Johnson county, Prestonsburg, Floyd county, Pikeville, Pike county; in the South Portsmouth District, Greenup county; in the Carrollton District, Carroll county; in the Louisville District, Jefferson county; in the Leitchfield-Tip Top District, Grayson and Hardin counties; in the Marion District, Crittenden county; in the Princeton-Dawson Springs District, Caldwell and Hopkins counties; in the Grand Rivers District, Livingston county; and in the Glasgow-Mammoth Cave District, Barren and Edmonson counties. Several other more or less isolated localities were also visited. All of these outcrops will be mentioned in the subsequent descriptions.

The above mentioned localities were studied to ascertain the area and thickness of the sands or sandstones involved, and the mineralogic composition of the various sands, for all sands do not consist entirely of quartz grains. The accessory minerals, such as the micas, muscovite and biotite; the feldspars, orthoclase and albite, may appear in massive sandstones, together with such injurious constituents as magnetite and pyrite which introduce their iron content into the batch and impart colors difficult to eradicate from the finished products.

Some attention was given to the limestone formations to ascertain which of these deposits within the state is best suited to serve as a flux in the treatment of the sand within the furnaces, for quartz sand is extremely refractory and requires limestone as a fluxing material. A few major calcite veins capable of furnishing a fluxing material that is practically chemically pure for the manufacture of the best types of glass were also investigated, as were also some fluorite veins, or spar veins as they are known in Kentucky, because fluorite is required in the manufacture of several kinds of glass.

Attention was also given to the size, angularity and mineralogical composition of the sand grains in various moulding sands, building sands, and gravel beds.

From nearly all of the above mentioned localities two samples were collected. One sample was sent to the Kentucky Geological Survey, Frankfort, Kentucky, where it has been labeled and placed on exhibition for the benefit of those who may be interested in glass sands; the other sample has been sent to the State Experiment Station, in the care of Dr. A. M. Peter, Lexington, Kentucky, for chemical analysis. The results of these analyses will appear later in this report and aid materially in determining the economic value of the different sands.

It was hoped that adequate time would be given for a petrographic study of all the sands and sandstones herein described, but the microscopic investigation under polarized light of at least a part of these products will have to be deferred.

A carefully prepared bibliography, showing it is believed the more important publications relating to sands and the glass sand industry, accompanies this report.

CHAPTER II.

DEFINITION AND PROPERTIES.

Few words in the English language are more difficult to define satisfactorily that glass. Many properties of the substance are necessarily involved in the definition. Diaphaneity, or the degree of transparency, is involved. To the average observer glass at once suggests transparency. Some true glasses are not transparent, while others are not even translucent.

Hardness, or the resistance to abrasion, is an important property. Hardness as applied to glass is capable of two different interpretations. One in the mineralogical sense as given above. The other bears reference to the resistance of glass to high temperatures. With the idea of fusion or melting of glass in mind we speak of glass as hard or soft. There are several minerals that have greater resistance to abrasion than glass. Even quartz which is the universal requisite in the manufacture of glass, cuts glass easily. Garnets are of superior hardness, likewise topaz, emery, corundum and its variety bort which is harder even than the crystalized gem. Superior hardness is also exhibited by the artificial product, carborundum, which is a silicide of carbon.

Tenacity which determines the degree of toughness of a substances is also involved. minerals and metals are found which are more brittle than glass.

However, there is one property that is common to all substances that may be classified as glass and that is an amorphous structure. Vitreous bodies are regarded as structureless solids. Most minerals and many inorganic substances when solidifying from either an aqueous solution or fusion assume a definite molecular arrangement or crystalline structure which often imparts to them a definite geometrical form. All of the hydrous oxides of iron save goethite would be illustrations of minerals whose tendency to assume a definite geometrical form is not sufficiently strong to cause them to crystallize.

According to Walter Rosenhain all bodies, whether liquid or solid, possess an ultimate structure, be it atomic, molecular, or electronic in character. The structure referred to in glass is not that of individual molecules, but the manner of grouping or aggregation of the molecules. The molecules in glass in the solid phase are not arranged in a definte grouping and the body therefore does not have a definite crystalline structure.

Evidence of this crystalline structure in minerals is often observed in quartz which is devoid of cleavage planes, in calcite in which the cleavage is parallel to the faces of a rhombohedron and therefore in three directions is perfect, and in zircon in which the crystallizing force is remarkably strong.

Vitreous bodies are characterized by the absence of crystalline structure and the optical, mechanical and chemical behavior of such bodies is consistent only with the assumption that their molecules possess the same arrangement, or rather lack of arrangement, as is found in liquids. True liquids in many cases pass into the vitreous state without undergoing any critical change or exhibiting any discontinuity of behavior as is exhibited during the freezing of a crystalline body. In the latter case the passage from the liquid to the solid takes place at one definite temperature and is accompanied by a considerable evolution of heat, so that the cooling of the mass is temporarily arrested.

In the case of glasses the passage from the liquid to the apparently solid condition is gradual and no evolution of heat or retardation of cooling has been observed.

Glasses then are congealed liquids. The process of congealing has involved no change of structure, and no new arrangement of the molecules. It simply implies the gradual stiffening of a liquid until the viscosity becomes so great that it behaves like a solid.

DEVITRIFICATION.

Glasses are capable of undergoing a change to the crystalline state when kept for a sufficient time at a suitable temperature. This process is analogous to the change that takes place in the feldspars and is known as devitrification.

Several samples of devitrified glass have been collected for petrographic study from the various factories visited this summer, but the results of this investigation may be too late for appearance in this report.

COMPOSITION.

Molten glass may be regarded as a mutual solution of a number of chemical substances, usually silicates and borates, and when cooled in the ordinary way these silicates and borates remain mutually dissolved, and ordinary glass is therefore a congealed solution.

The most important anhydride that appears in glass is silica, SiO_2. Other acid oxides often present in special glasses such as those used for optical purposes and in chemical laboratories are boron trioxide, B_2O_3, and phosphoric anhydride, P_2O_5.

The most common basic oxides in glass are lime, CaO, sodium oxide, Na_2O, potassium oxide, K_2O, lead oxide, PbO.

The lead oxide does not appear in the analysis of window glass, but it does occur in lime flint glass.

Other basic oxides like magnesium oxide, MgO, and manganous oxide, MnO, also appear in lime flint glass.

The actual chemical analysis of photo glass as manufactured by the American Window Glass Company for the Eastman Kodak Company of Rochester, N. Y., is of interest and is given here as follows:

SiO_2	73.06
CaO	12.68
Na_2O	11.86
MgO	.16
Fe_2O_3	.12
SO_3	.66
	98.54

The specific gravity of this glass is 2.552 and the quality is considered excellent.

The following table gives the maximum and minimum percentage of impurities in the constituents of optical glass, and is taken from Procedures in the Manufacture of Optical Glass by Williams and Rand[1].

	Fe_2O_3		SO_3		Cl	
Chem.	Max.	Min.	Max.	Min.	Max.	Min.
$BaCO_3$	.009	.0005	.12	.0774	.13	.01
C. P. $BaCO_3$	.0067	.0043	.08	.018	.069	.0124
Pb_3O_4	.0056	.0015	.055	.01	.13	.017
Na_2CO_3	.003	.0014	.03	.0049	....	....
$Ca(OH)_2$	.048	.026	.167	.06	....	....
K_2CO_3	.01	.004	.07	.018	.31	.11
ZnO	.006	.0057	.327	.11	.35	.078
KNO_3	.0019	.0007	.0016	....	.07	.05
$Na_2B_4O_7$	.002	.0004	.034	.018	.005	.0024
H_3BO_3	....	....	....	....	....	....
Al_2O_3	.0022	.0022	.15	.15	....	....
TiO_2	.02	.0048	....	....	....	....

[1]Journal of American Ceramic Society, Vol. II, No. 6, p. 425.
[2]Geol. Sur. Penn., Report No. XII, pp. 22, 23.

The following tables showing the composition of window glass, plate glass and lime flint glass were taken from the work of Prof. Charles R. Fettke on Glass Manufacture and the Glass Sand Industry of Pennsylvania.

WINDOW GLASS.

	American	American	Belgian	English	English	English
	(1)	(7)	(1)	(1)	(2)	(4)
SiO_2	72.26	71.00	69.48	71.40	72.00	69.6
Al_2O_3	1.42	1 to 2	2.59	1.90	2.00	1.4
Fe_2O_3						.4*
MgO			.26			
CaO	13.34	13.00	13.40	12.40	13.00	13.4
Na_2O	14.01	14.00	14.55	15.00	13.00	15.2
Total	101.03	100.00	100.28	100.70	100.00	100.00

*Including MnO_2

WINDOW GLASS—Continued

	English	French	French	German	German
	(4)	(1)	(2)	(1)	(5)
SiO_2	72.5	69.05	71.9	72.68	71.23
Al_2O_3	1.00	1.82	1.4	1.06	1.70
Fe_2O_3	.4*				
MgO				.26	.20
CaO	13.1	13.31	13.6	12.76	16.39
Na_2O	13.0	15.22	13.1	13.25	10.78
Total	100.0	100.00	100.0	100.00	100.30

*Including MnO_2.

PLATE GLASS

	American	American	Belgian	English	English	English	English
	(1)	(7)	(1)	(1)	(4)	(4)	(4)
SiO_2	71.2	71.0	72.4	78.64	72.0	73.2	75.2
Al_2O_3 / Fe_2O_3	1.0	1.0 to 2.0	....	2.68	.5	.4	.9
MgO	....	....	....	....	....	....	....
CaO	14.2	13.0	13.2	6.09	8.5	13.6	6.9
Na_2O	13.9	14.6	14.4	11.63	19.0	12.8	17.0
K_2O	....	....	....	....	....	....	....
Total	100.3	100.0	100.0	100.38	100.0	100.0	100.0

PLATE GLASS—Continued

	French	French	German	German	German
	(1)	(2)	(5)	(6)	(6)
SiO_2	72.1	71.80	70.58	77.00	73.00
Al_2O_3	....	1.26	1.01	....	....
Fe_2O_3	....	.14	.80	....	....
MgO	....	....	....	....	....
CaO	12.2	15.70	16.07	7.40	15.20
Na_2O	15.7	11.10	11.77	15.50	11.80
K_2O	....	....	....	....	....
Total	100.0	100.00	100.23	99.90	100.00

LIME FLINT GLASS

	American	French	French	French	German	German	Russian
	(1)	(1)	(6)	(6)	(1)	(6)	(6)
SiO_2	73.96	69.6	77.3	72.0	75.61	78.4	74.7
Al_2O_3			trace	4.5	1.01	.2	.4
	.44	5.2					
Fe_2O_3						.2	.1
MgO	.41	.....	.....	.....	.....	.....	.....
CaO	13.94	13.0	6.4	6.4	7.38	7.1	8.8
Na_2O	.....	3.0	16.3	17.0	.....	13.9	15.7
	10.85	.....	.....	.....	.....	.....	.....
K_2O	.....	8.0	.....	.....	11.39	.....	.....
PbO	.18	.....	.....	.....	4.84	.....	.....
MnO	.....	.....	.....	.....	.....	.2	.2
Total	99.78	99.8	100.0	99.9	100.23	100.0	99.9

Industrial glasses are mixed silicates of a few bases. The alkaline earths, barium, strontium, calcium; the alkalies, sodium, potassium, lithium; the metals, iron, aluminum, lead. Most of these are usually present in small quantities. Certain special glasses designed for scientific purposes, optical lenses, and glass intended to resist unusual treatment, may vary from the above compounds.

Glasses, therefore, are not definite chemical compounds, but solutions of definite compounds in one another.

It has often been stated at the various factories visited that their glass corresponds in formula to that of the soda-lime feldspar, oligoclase (Ca Na_2) O, Al_2O_3, 6SiO, but the silica content is greater than that of oligoclase. Therefore the inference is drawn that free silica, SiO_2, still remains in the glass. The formula as given at another plant for its product was RO, 2½ SiO_2.

CRITICAL TEMPERATURE.

There are in glass two opposing forces. One an increasing tendency towards crystallization, and the other a more rapidly increasing resistance toward crystallization. This marks the critical range of

temperature. If the former force gains control of the molten solution then crystallites or spherulites will appear in the cooled product. Some of these have been observed in certain factories visited in the scrap glass which is required in feeding a new batch into the furnace.

In another instance a layer of devitrified glass varying from one to two inches in thickness was found within and around the margin of the furnace.

WEATHERING OF GLASS.

Glasses betray their chemical composition by their behavior towards atmospheric agents, such as moisture and carbon dioxide. A glass rich in alkalies is hydroscopic and slowly undergoes decomposition on exposure to damp atmosphere.

Glass is not the stable material many people have supposed it to be. Pure water even at normal temperature slowly dissolves some of the alkali silicates which in inferior glass constitutes more than 15 per cent. Warm water under pressure is an active corroding agent. This result is often seen in the glass tubes of steam boilers.

Water charged with carbon dioxide in solution is a weaker solvent than pure water and water containing alkaline substances is a far greater solvent. The effect of alkalies upon glass is often observed around the stoppers of bottles in various laboratories.

The one acid that dissolves glass readily is the ever active hydrofluoric acid, HF. Prolonged exposure to sunlight, sunlight at high altitudes and ultra violet light will produce a change in color in the glass by transferring the oxygen from the oxide to silicate.

Glasses containing manganese assume a purple or brown tint on long exposure to the atmosphere. Emanations of radium will effect the same result.

MECHANICAL PROPERTIES.

The destructive effect of wind blown sand has often been observed in stained glass memorial windows. The mechanical properties are of considerable importance in glasses designed for specific uses as the gauge tubes of high pressure boilers, porthole glasses in ships, glass prisms inserted in pavement lights, and bottles containing effervescent liquids. Such objects are subject from time to time to a considerable stress and strain.

PLASTICITY

The strongly refractory oxides of lead and barium impart to flint and barium glasses their brilliancy and weight.

For combustion tubing, which must resist red heat, lime, CaO, magnesia, MgO, and aluminum, Al_2O_3, are used in the highest possible proportions.

As will be seen later in ordinary glass, limestone or burned lime, and sodium carbonate are the fluxing agents used with the quartz sand, but such glasses are not highly refractory. The most refractory glasses should show little or no plasticity at 500 degrees Centigrade.

STRENGTH OF GLASS.

Winklemann and Schott* give the tensile strength of glass as varying from 2 to 5½ tons per square inch, and the crushing strength as varying from 3 to 8 tons per square inch.

TRANSPARENCY.

The most highly valued property of glass is its transparency. This is the fundamental and essential property which leads to the employment of glass in the place of either stronger or weaker materials. The two uses where transmission of light is not involved are (1) opal glass for covering walls, and (2) pressed glass blocks for paving purposes.

OPTICAL PROPERTIES OF GLASS

Glass is very sensitive to the variations that arise in the chemical composition and the various methods utilized in its manufacture. Homogeneity is one of the most essential requisites of optical glass. Homogeneity demands the same density throughout the mass. Ordinary glass never possesses perfect homogeneity. When a thick piece of such glass is examined threads or layers of different density can be observed in the form of minute irregularities in the glass. These defects are known as veins or striae to the manufacturers and these threads must be avoided in the better kinds of optical glass. Seeds are quite common in the cheaper kinds of glass and are always objectionable imperfections.

*See Rosenhain Glass Manufacture, p. 19.

CHAPTER III.

HISTORY OF GLASS IN THE UNITED STATES.

Prior to the coming of the European Colonists the only glass known in America was obsidian, or volcanic glass. In 1608 some glass makers were among the artisans brought to Jamestown, Virginia, but the craze for tobacco interfered with their industry. In 1621 several Italian glass makers were imported to manufacture beads for the Indians. In 1639 a glasshouse was erected at Salem, Massachusetts.

Prior to 1654 a glassmaker, Jan Smeedes, received an allotment of land on Manhattan Island and the business which he carried on gave the name Glassmakers street to the present South William street of New York City. In 1683 William Penn alludes to a glass house in Pennsylvania.

In 1754 a Dutch gentleman, Bamber, built glass works in Brooklyn, N. Y., and the first bottle blown by him bearing his name and the date of manufacture is in the collection of the Long Island Historical Society, Brooklyn, N. Y. Glassboro, N. J., was founded by a colony of German glassmakers who moved there in 1775. In 1787 the Massachusetts Legislature gave to a Boston glass company the exclusive right to make glass in the state of Massachusetts for 15 years. This is said to be the first successful glass factory in the United States.

Pittsburgh, Pennsylvania, first manufactured glass in 1796, and is still a most important glass making center. At the very beginning of the industry in Pennsylvania coal was used instead of the traditional wood for fuel. This, with the abundance of excellent sand in the adjacent rivers, gave the industry a phenomenal development in the Keystone State, which industry has been increased by the substitution of gas and oil fuels.

In 1827 pressed glass was invented by a carpenter of Sandwich, Massachusetts. With the discovery of a cheaper and better fuel in the form of natural gas the center of glass making moved west of the Alleghanies, where it still remains.

By the close of 1880 the census report shows that the glass industry of the United States has been brought to a very extensive and prosperous condition. There were at that time 211 factories, employing 24,177 men, and sending out an annual product worth $21,154,-571.

In 1890 the number of factories had increased to 294 and the value of the finished product to $41,051,004. In 1909 there were 363 establishments for the manufacture of glass and the product was valued at $92,095,203. In 1917, the latest date for which statistics are complete, the finished product was valued at $2,685,014.

Within recent years artistic glassware of great beauty has been produced in the United States. Notable examples of such ware are the stained glass windows, and the mosaics of leading makers, such as La Farge, and Tiffany, and the famous Favrille glass of the Tiffany Company of New York City. The United States still imports more glass than she exports. The exports are largely that peculiar product of human ingenuity known as pressed glass.

HISTORY OF THE FUELS.

Ten different kinds of fuel have been used in the manufacture of glass. (1) Kiln dried wood. The wood was split into pieces about two inches in diameter and thoroughly dried. (2) Unkilned wood. The wood was piled up in a cave or cleft in the rocks. The burning of the green wood in large masses produced the required heat for the fusion of the batch. (3) Bituminous coal. (4) Resins as solids. This fuel proved unsatisfactory and it was replaced by liquid resins. (5) Resins as liquids. (6) Coal tar. (7) Anthracite coal. (8) Natural gas, which is the ideal fuel. (9) Producer gas manufactured from soft coal. This fuel proves fairly satisfactory. Many of the factories in West Virginia are equipped with plants for the manufacture of producer gas at any time when the supply of natural gas becomes inadequate. (10) Petroleum. A few plants only have oil burners. Oil burners have been used in Pennsylvania with fairly satisfactory results.

GLASS FACTORIES IN KENTUCKY.

As far as could be ascertained a glass factory was in active operation for several years at Covington, Ky. This company is said to have obtained its sand from the Ohio river at Sandy City and Zelda, Ky. When natural gas became available as a fuel in Indiana the plant was removed from Covington, Kentucky, to Indiana, that it might take advantage of the ideal fuel. The date of this removal could not be ascertained.

It is definitely known that in 1906 two glass factories were manufacturing glass in Kentucky, one at Frankfort, and the other at Owensboro. Neither of these factories are in operation at the present time. A factory was also reported to have existed at one time at Paducah in the southwestern part of the state on the Ohio river and to have used the sands of the Ohio river as the chief source of its raw material.

There is however in Ashland, Ky., Boyd county, in the eastern part of the state, in active operation today the Ashland Glass Company, with F. A. Demer, superintendent. It is a cutting and decorating plant that does most excellent work. The glass ware comes to the plant from various factories in the form of flint glass blanks. The decora-

tions are largely in the molds in which the glass ware is pressed and the final decorating is done at the Ashland plant. This work consists of cutting, polishing, and producing a frosted effect either by grinding or by wind blown sand.

The National Mirror and Sand Blasting Company which was located at 138 N. Fourth street, Louisville, Jefferson county, Kentucky, has recently sold out its equipment to Wolf Blitz, 415 W. Market street. Plate glass is here cut, beveled, and fitted to table tops. Mirrors silvered and glass ground or sand blasted. The plant does not manufacture the glass itself, but purchases it in the open market and distributes the finished products.

Other plants in Louisville handling glass in a similar manner are the Central Glass Company, 3003 W. Broadway, and the Kentucky Mirror Works, 131 N. Fourth street.

CHAPTER V.

SANDS.

Sand is a loose incoherent mass of mineral materials in a finely granular condition. Usually the predominating mineral is quartz, with a small proportion of mica, feldspar, magnetite, and other resistant minerals. It is the product of the chemical and mechanical disintegration of rocks under the influence of weathering and abrasion. When freshly formed the particles are usually angular and sharply pointed, becoming small and more rounded by attrition as they are blown about by the wind, or transported by water.

Sand is an important constituent of most soils and is extremely abundant as a surface deposit along the courses of rivers, on the shores of lakes and seas and in arid regions. Of the many mineral resources of the country few, if any, are more abundant and in quality and use more important than sand. The agriculturist, the builder, the metal founder, the brick maker, the road builder, the glassmaker and the housewife all turn in their need to the natural sand resources of the country.

For their intelligent use a thorough knowledge is necessitated of the sands themselves, their mode of occurrence, and their physical and chemical properties. An investigation is also needed of the materials previously used in the sand utilizing industries. The questions have often been raised why will one sand make an exceedingly strong and resistant cement, and another only a weak, friable product? Why will one sand adhere to metal in a foundry and another leave the metal perfectly clean? Why will one sand produce a clear, sparkling water white glass fit for table ware or optical instruments, and another only a green bottle glass?

As already noted in the definition given above, sands consist mostly of silica in the form of broken grains of crystalline quartz, associated with various impurities, partly impregnating or coating the quartz, and partly in the form of grains of dust or minute pebbles or other constituents.

When sand is used in glassmaking the most obvious requirement is that it should be as pure as possible, uniform in size, and especially free from all ingredients which would diminish the utility or beauty of the finished product. However, for other purposes the impurities themselves may give the sand its specal value. In some industries the hardness and shape of the grains themselves are more essential than the actual mineralogical composition, and the difference between angular and well rounded grains becomes important.

Sand for the manufacture of glass must be used in such large quantities that the deposits must be abundant, reasonably soft and

friable, easily and cheaply worked. If the deposit is a loosely cohering consolidated sandstone, the seams and beds should run evenly in nature and composition and be closely marked off from other formations. Another important factor in the glass sand industry is an easily accessible market for both the sands themselves and the finished products.

The term glass sand usually connotes a limited range of chemical and mineralogical composition and a definite grade. The term may include other minerals than quartz, SiO_2, of varying grades irrespective of composition or angularity. The term is also applied to consolidated sandstones and even hard siliceous rocks which have been crushed for commercial purposes.

USES OF SAND.

1. Sands bearing minerals of the rare earths, such as monazite, xenotime, thorianite, zircon, etc., which are worked for the rare elements cerium, lanthanum, didymium, yttrium, thorium, etc., whose oxides are used in the manufacture of incandescent mantles and filaments, and for refractory points.

2. Those bearing the precious metals, gold, Au, and platinum, Pt, whose high commercial value always lends interest to placer mining. Also wolframite, $FeMnWO_4$, which is a possible source of the rare and highly valued element tungsten, and cassiterite, SnO_2, the most important source of tin.

3. Sands bearing diamonds, rubies, and other gems for the jewelry trade.

4. Those containing large quantities of shells and organic matter which occur along certain shores of rivers, lakes, ponds, etc., and are used either direct as fertilizers or pulverized and used in the manufacture of fertilizers.

5. Abrasive sands which depend for value upon the hardness, toughness, sharpness, etc., of the individual grains. Quartz is hard without cleavage, breaks with a conchoidal fracture and does not easily comminute under wear.

6. Friction sands which are used to increase the grip of car wheels on grades for both steam and electric lines.

7. Building sand. Most sands are suitable for mixing with lime and water for mortar which is so extensively used in building purposes. In building sand is included a sand suited for the manufacture of cement, and a coarse sharp sand that can be mixed with gravel in the manufacture of concrete.

8. Brick making sands. Sands that may be mixed with a clay that is too plastic for the manufacture of ordinary brick. Sand used in the manufacture of sand-lime brick, and refractory sand used in the manufacture of fire brick.

9. Parting sands. These must be dry, sharp, fine and quartzose sands.

10. Filtration sands. These sands are used in the purification of water and in large filter beds for the disposal of municipal sewage.

11. Chemical sands. Such sands must be refractory at high temperatures. They must contain a high percentage of quartz grains and little or no fluxing materials. Silica brick for assay furnaces, glassmaking furnaces, glass pots, also gas ovens, demand resistance to high temperatures. In many instances they must resist also the solvent action of the materials contained.

12. Molding sands. The term molding sand is used to embrace those sands which are used in the iron foundries as a mold in which the metal is cast. It must be sufficiently clean to prevent the metal from adhering to the molds. The term also includes those sands which are used on the floors of plants manufacturing brick to keep the green brick from sticking to the floor, and also on the inside of the mold in which the brick are pressed.

13. Ballast sand. This includes the sands used as ballast along the great railways of America. Such sand is also used as a road metal in the manufacture of permanent roads in localities where the road bed is too rich in clay.

14. Belt sand. Sand used on belts to keep them from slipping.

15. Core sand. Sand used as a core in making castings for machinery.

16. Roofing sand. Sand that may be mixed with a binder and fashioned into roofing material.

17. China sand. Sand used in the manufacture of china ware.

18. Pottery sand. Sand used in the manufacture of pottery. It is added to a pottery clay that is too fat.

19. Sand blast sand. Sand used as a sand blast in the production of the frosted effect upon glassware, as an abrasive in the finishing of metallic products, and as an abrasive in the cleaning of the exterior of stone buildings.

20. Glass sands. This term embraces all forms of sand that are suitable for the manufacture of glass. One sand may make ordinary bottles and be entirely unsuited for the manufacture of plate glass or the fine water white stem ware of the dining room.

Glass sand is obtained from various river deposits which are unconsolidated. Such sands require washing to rid them of impurities such as clayey matter, iron grains and scales of mica. They must also be screened to a uniform size. Glass sand is also derived from loosely cohering sandstones by crushing them so as to free the individual grains from each other. It may also be obtained from quartzites by crushing them to the desired fineness.

Silica is the chief constituent of glass sand. The natural impurities such as iron oxides, iron sulphides, alumina, titanium oxide, lime,

and magnesia, should be present only in very small quantites. Some manufacturers, however, believe the injurious effects of alumina and magnesia are over estimated.

The grains of sand may be either rounded or angular, but an approximate uniformity in the size of the individual grains is desirable, and should range between 30 and 120 mesh. If the grains are larger than 30 mesh they are difficult to fuse in the furnace. If they are finer than 120 mesh they burn out in the batch.

SIEVE TESTS.

The following table of sieve tests will be of interest here.

Locality	Sample	Passed 20 mesh	Passed 40 mesh	Passed 60 mesh	Passed 100 mesh
Ottawa, Ill.	Finest grain	100%	100%	92%	25%
Ottawa, Ill.	Coarsest grain	99	6	1	0
Gray's Summit, Mo.	Crude	100	88	55	1
Gray's Summit, Mo.	Finished	100	92	25	2

GEOLOGIC HORIZONS.

Glass sands are obtained from a number of different geologic horizons ranging in age from the Cambrian to the Pleistocene. The Pleistocene, and most of the Cretaceous and Tertiary deposits are unconsolidated sands. Those ranging in age from the Cambrian to the Carboniferous are consolidated, therefore quartzites and sandstones, and need to be crushed before they can be used in the manufacture of glass.

CHEMICAL COMPOSITION.

A table of chemical analyses of some of the more important glass sands is given here to show the general requirements in purity, but a chapter on analyses will appear later in this report.

Locality	Sample	Constituents SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO
Ottawa Ill.	River sand	99.95	0.3	0.0	0.13	tr
Massillion, Ohio	Crushed sandstone	97.50	1.50	0.50	0.0	0.50
Cheshire, Mass.	Crushed Cambrian Quartzite	99.46	0.48	0.0	0.06	0.0
Hanover, N. J.	Tertiary sand	97.705	0.755	0.15	0.955	0.442
Sturgisson, W. Va.	Deckers creek sandstone	99.15	0.6517	0.0383	....	....
Berkeley Springs, W. Va.	Oriskany sandstone	99.580	0.199	0.068	....	....
Tip Top, Ky.	Big Clifty sandstone	99.14	0.23	0.02	0.21	0.08
Tip Top, Ky.	Big Clifty sandstone	98.87	0.21	0.08	0.24	0.12
Madisonville, Ky.	Big Clifty sandstone	98.68	0.17	0.15	0.33	....
Cacapon Mt., W. Va.	Medina Sandstone	99.86	0.23	0.66	....	....

ORIGIN OF SANDS.

Sands are the result of the gradual disintegration of rock masses. The expansion and contraction due to changes in temperature play an important part in their formation.

Rain not only dissolves the more soluble cements binding sand grains together, but also thoroughly saturates the stone with water, filling the interstices among the sand grains so that when the temperature falls below zero the pressure is equal to the weight of a column of ice one mile high. Frost, therefore, is an important factor. Gravity is also a geologic agency engaged in the work of disintegration and

ially reduced in size by wear and tear, and broken up into their constituent mineral grains.

The corrosive agents in the atmosphere such as carbon dioxide, ozone, hydrochloric acid, nitric acid, etc., assist in this work. The sulphuric acid formed from the decomposition of sulphides in the presence of circulating ground waters assists in the work. The soluble constituents of rock masses are carried away in solution, while the more resistant and insoluble particles remain behind as sand. Feldspar grains may be kaolinized and part of this fine clayey matter may be transported a considerable distance, while a part may remain among the sand grains. Minute scales of mica are not uncommon in sandy deposits.

One result of the continuous disintegration of rock masses is the production of simple individual mineral grains which may vary both in size and composition. These individual residual grains are transported downwards toward the sea and collected whenever the velocity of a stream is so checked that its burden of siliceous sediment is greater than it can bear. In transit it is washed by waters and may be winnowed by winds along dry shores. The sorting of the material is controlled by the size and specific gravity of the individual sand grains. The larger and the denser mineral grains are the first to be dropped. The sorting is never perfect, but occasionally there may be found a deposit made up of one mineral with its sand grains practically of uniform size. The fine materials such as silt and clay will not usually yield beds of sediments of exactly the same grade. The very mode of transportation favors mixture of materials.

The tendency of the transported material is to collect in basins. The heavier and the larger fragments are dropped first, while the finest material may be carried long distances from its point of derivation. The normal order of deposition would be gravel, sand, silt and mud, but the grading of material by air and water is not perfect. Torrential deposits formed by the sudden arrest of materials near their source of derivation result in the deposition of both coarse and fine products, and the material is, therefore, non-graded.

ASSOCIATED MINERALS.

Glass sands should contain only a small proportion of sand grains other than quartz. The heavy detrital minerals which possess a specific gravity greater than that of quartz, 2.65, should not exceed 0.02 per cent. In certain sands not suitable for the manufacture of glass they may reach as high as 5 per cent, and in a few instances even greater proportions. The black sands of the Adirondacks in New York are essentially magnetite. These accessory minerals may be divided into seven different groups:

1. The oxides: Anatase, brookite, cassiterite, corundum, hematite, limonite, magnetite, rutile and spinel.
2. The sulphides: Marcasite, pyrite and pyrrhotite.
3. The carbonates: Calcite, dolomite and magnesite.
4. The phosphates: Apatite and monazite.
5. The silicates: Albite, andalusite, angite, biotite, cyanite, enstatite, epidote, garnet, glauconite, hornblende, hypersthene, muscovite, olivine, orthoclase, sillimanite, sphene, staurolite, topaz, tourmaline and zircon.
6. The titanate, ilmenite, and the tungstate, wolframite.
7. The organic compounds: Anthracite and bituminous coal.

The last two products may be especially abundant in regions where coal mines are operated, or where the streams transporting sediments have cut through coal bearing formations.

The mineral content of sediments will vary with the composition of the rocks from which they are derived, the distance transported from the source of origin, the grade of the streams serving as the transporting agent.

REFRACTORINESS OF SANDS.

One property of the oxides which is of primary importance is the melting point. The following table of melting points is of interest:

	Degrees
Quartz, SiO_2,	below 1470
Christobalite, SiO_2,	1625
Alumina, Al_2O_3	2050
Lime, CaO,	2570
Magnesia, MgO,	2800
Magnetite, Fe_3O_4,	1580
Hematite, Fe_2O_3,	Unknown
Ferrous oxide, FeO,	Unknown

Two melting points are here given for silica, SiO_2. The explanation introduces the very interesting seat of allotropic forms that silica exhibits. Silica possesses in an unusual degree the property of responding slowly to changes in temperature as regards its melting point and its transitions from one principal form to another. The principal forms are quartz, tridymite and christobalite. By rapid heating quartz can be melted before it has time to transform into tridymite or christobalite.

CHAPTER VI.

RAW MATERIALS

ACID OXIDES.

The glass industry is largely dependent for its raw materials upon the mineral deposits of sand, sandstones, quartzites, limestones, fluorites, etc. The investigation of these materials began in the Mississippi valley in 1905. It was resumed in the Ohio valley in 1906. It was systematically taken up in West Virginia in 1909; in Pennsylvania in 1919, and in Kentucky in 1920.

It is of interest to note the source of the materials used in the manufacture of glass, to compare their cost with that of other materials, and to consider whether any economies can be effected in their production. All the sands that can be produced of sufficient purity even for green and amber bottles find a ready and waiting market at good prices. Glass factories are best located in the great gas belts, for natural gas is the ideal fuel; in the soft coal fields where producer gas may readily be manufactured, and in oil fields where petroleum may serve as the fuel.

The raw materials comprise a group of substances that are melted together to form the body of the glass, to bring about a change in the raw substances, but which are not necessary for the formation of the glass itself. The last group is used to clarify, color or decolorize glass.

QUARTZ, SiO_2.

Quartz sand is by far the most important constituent entering into the manufacture of glass. In the technical sense all glasses have silica as an essential constituent. It can be replaced only in small percentages by other acid oxides, as in optical glass.

Silicon, next to oxygen, is the most abundant element in the crust of the earth. It combines with oxygen in the formation of quartz, SiO_2, and its numerous crystalline, or wholly vitreous varieties; its cryptocrystalline, or flint-like varieties; its opaline, or hydrated varieties. It also enters into the composition of all hydrous and anhydrous silicates.

Although quartz forms about 12 per cent of the lithosphere only a few of the many occurrences are sufficiently free from impurities to be of special interest to the glass manufacturer. Pure quartz sands, white or yellowish white in color, and varying in size from 0.1 to 0.4 millimeters in diameter, furnish practically the sole source of silica for the glass industry. These may be derived from either the unconsolidated sands like those of Ottawa, Ill., or consolidated sands like those of Berkeley Springs, W. Va.

The rocks used in Indiana for glass sand occur in the Silurian, Devonian, Carboniferous and Tertiary formations. At Pendleton, Ind., there is an outcrop of Devonian sandstone that varies from 7 to 15 feet in thickness. It is soft, friable, white in color, and sufficiently pure to be used as a glass sand.

The Mansfield sandstone, or millstone grit, is of Carboniferous age. It is the basal (Pottsville) conglomerate member of the Pennsylvanian series, and is more important in the glass sand industry of the state than any other formation.

The Tertiary deposits of sand, gravel, and in places conglomerates, occur on the high points of the upland bordering the Ohio river flood plain in Indiana and Kentucky. Burchard refers the glass sands of Tip Toy, Kentucky, to the same Tertiary formations. This formation will be discussed later with the other glass sands of Kentucky.

According to G. P. Grimsley the most important center of the glass sand production of West Virginia is near Berkeley Springs in Morgan county, where the Oriskany white sandstone near the summit of Warm Spring Ridge has long been quarried, crushed and shipped to the glass manufacturers. Warm Spring Ridge extends from the Potomac river opposite Hancock, Md., southwesterly for a distance of 8 or 10 miles with a strike of north 25 to 30 degrees east, and an elevation of 1000 to 1100 feet, decreasing to 800 to 700 feet at the northern end. The crest of the ridge is composed of a thick stratum of white Oriskany sandstone that is extensively worked as a glass sand.

The Pennsylvania Glass Sand Company, of Lewiston, Pa., the West Virginia and Pennsylvania Sand Company of Baltimore, Md., and the Berkeley Springs Sand Company, manufacture glass sands of high grade from this pure white Oriskany sandstone. Most of the factories visited in West Virginia use this sand in the manufacture of glass.

The Great Cacapon Silica Sand Company, of Pittsburgh, Pa., manufactures glass sand from the Medina white sandstone on the west slope of Cacapon mountain. The Deckers Creek Stone and Sand Company, of Sturgisson, W. Va., manufactures glass sand from the sandstone at Deckers creek. The sandstone is 40 to 50 feet in thickness, of which only 35 feet is worked as glass sand. The upper portion is somewhat richer in impurities than the lower beds, and the product is sold for building sand. The lower beds make a high grade glass sand. This condition holds true of several of the sandstones in Kentucky, as will be seen later in this report.

SELECTION OF SANDS.

Glass cannot be purified by crystallization or filtration. The fixed products that enter into the furnace must appear in the finished ware. Therefore, great care must be exercised in the selection of the raw

Certain volatile acid constituents are eliminated in the process of burning, as the carbon dioxide, CO_2, of soda ash, but this is used as a fluxing material. Even the quantity of water contained in a ton of glass sand appreciably affects the composition of the resulting glass. Sand, therefore, must be perfectly dry. If it is shipped wet to the various factories from plants without dryers, then the sand must be thoroughly dried at the factory before mixing the batch.

REQUIREMENTS OF GLASS SANDS.

1. The sands must be thoroughly dried. If the water used in the washing of the sand has not been driven off by artificial heat or exposure to the sun's rays, not only will the finished product be affected but difficulties also will arise in mixing the batch.

2. The sand must be essentially pure white quartz grains, free from clayey matter and the pale yellowish or brownish coating of iron oxide so frequently seen in sand.

3. The sand must be of uniform mineral composition, or the quality of the glass will fall off, or the glass will refuse to melt freely at the temperature desired. Its chemical analysis should show not less than 99 per cent of silica, and some analyses will reach 99.97 per cent silica. One factory visited this summer placed its requirement as high as 99.99 per cent silica, with the maximum limit of iron oxide at 0.005 per cent. A sand of that purity would be extremely difficult to obtain, and the glass manufactured from such sand should be the very best glass possible to produce.

4. Uniformity of size in the individual grains is required. A few of the superintendents of plants visited place evenness of the sand grains on an equality with a very high silica content. Just how far an even melting of a batch depends on the shape of the sand grains is not definitely known, but it is obvious that sand grains of uniform shape will mix and melt more readily than one whose grains are angular, subangular and rounded fragments.

Elutriation, or the classification of sands according to size by means of upward currents of water, is carried out on the assumption that the material is composed entirely of quartz or minerals of the same density. Most glass sands contain so small a percentage of the heavier or lighter minerals that the error introduced by the latter is less than that due to experimental causes.

Mechanical analyses now successfully used in the preparation of glass sands require that the sand shall be up to 90 per cent approximately the same grade. Sand grains more than 1 mm. in diameter appreciably reduce the commercial value of the sand. The better sands should have no grains more than 0.5 mm. in diameter. Higher

temperatures are required to fuse the coarser material. A longer time is consumed in the process of fusion. The coarser material may remain undigested or partly digested in the glass.

Finely powdered silica in a poorly graded sand is objectionable. It causes an appreciable loss due to the fine material being carried over by the blast of air and gas before it melts. As a result there is both a loss in the bulk of material desired and a change in the composition of the finished product.

5. Angularity of sand grains.

According to Bulletin 285, p. 454, of the U. S. Geological Survey, glass sands composed of well rounded grains have been successfully utilized in glass manufacture. Sands consisting entirely of well rounded and water worn grains have not, however, been popular in the factories visited. Angular sands fuse more rapidly, for the fusion begins on the corners and edges, and the surface area, volume per volume, is greater.

6. Freedom from clays.

Sands to be used in the manufacture of glass should not contain an appreciable amount of silt or clayey matter. Clayey materials tend to cloud the glass. Kaolinite itself is highly refractory and renders a sand containing this mineral unsuitable for use in the manufacture of glass.

7. Freedom from iron.

For nearly all kinds of glass the iron oxide, Fe_2O_3, percentage should be as low as possible and preferably less than 1 per cent. This higher limit is permissible in the manufacture of the cheapest green bottles. For the best varieties of glass such as optical glass, flint glass, plate glass, water white stem ware, the iron content in the sand used may vary from 0.02 to 0.08 per cent. As previously noted the maximum iron content in sand permitted by one company visited was 0.005.

The introduction, however, of selenium, Se, as a decolorizer makes possible the use of sands containing more than 1 per cent of iron oxide. Selenium is a rare and expensive element, and the use of much selenium adds to the cost of the finished product. One factory reported that the color of glass could be controlled perfectly by the use of selenium even with 2 per cent of iron oxide in the sand.

8. Freedom from alumina, lime and magnesia.

These are refractory oxides with higher melting points than silica, and therefore they lengthen the time required in the process of fusion. The almuina arises largely, in addition to kaolinite particles already noted, from the feldspar grains and grains of ferromagnesian minerals that may be present in the sand. The lime arises from the calcareous cements binding the sand grains together or the coating of calcium carbonate upon the individual sand grains. The magnesia arises largely from the minute grains of various ferromagnesian minerals in the sand.

CHAPTER VII.

RAW MATERIALS—Continued.

BASIC OXIDES.

LIME, CaO.

All of the sixty-six factories visited this summer use limestone as a flux in the treatment of their silica. It enters into the glass itself as is shown in the analysis of lime, flint, plate, window, and bottle glass. It imparts smoothness and brilliancy to the glass. It increases the resistance of glass to the action of corrosives. It hardens the glass, renders it brittle, makes it more difficult to work, and demands greater care in the process of annealing. Furthermore it tends to prevent the formation of cords. It increases the fusibility of the glass and also its tendency to devitrify.

According to Frink when glass contains more than 12.83 per cent of lime it is hard, brittle and difficult to fuse into a perfect glass. Hardness and tenacity will increase up to a content of 13.2 per cent of lime, after which these properties rapidly diminish.

The source of the lime used in the glass industry is mainly from beds of sedimentary limestone that are reasonably free from impurities. A limestone is any rock mass consisting essentially of calcium carbonate, $CaCO_3$. Yet all rock masses falling within this definition are not suited for use in the manufacture of glass. Small quantities of slica, magnesia, iron oxides, clayey matter and organic substances may be present. The most of these impurities should be present in exceedingly small quantities.

If the silica is present as minute, well rounded or angular quartz grains it is far less objectionable than when flint or chert concretions are present. If these minerals are present in the crushed limestone, they not only prove very refractory, but also remain as opaque enclosures, or, as the manufacturer says, "stones," in the finished product.

As the iron content is the most dreaded impurity in the sand used in the manufacture of glass, so is the iron content the most objectionable impurity in the limestones used in fluxing the silica. True it is that the quantity of limestone used in a given batch is much smaller than the quantity of silica, and therefore, the percentage of iron may be a little higher than that permitted in the sands used.

Many of the glass factories visited have limited the iron content in the limestones used to 0.5 per cent iron oxide, but Rosenhain in his masterful book on Glass Manufacture states that it should not exceed 0.3 per cent iron oxide.

For the percentage of iron in the limestones largely used as a flux in the glass sand industry, and others that may be utilized, see the chapter on analyses of limestones for fluxing materlais which appears later in this book.

In the different factories visited the lime was added in four different ways.

1. Crushed limestone, $CaCO_3$, mostly from Martinsburg, W. Va., and the oolitic limestone from Bedford, Indiana.

2. Calcite, $CaCO_3$, practically chemically pure calcium carbonate, obtained from the Chinn Mineral Company, miners and manufacturers of calcium carbonate and perfection whiting, whose office is in Lexington, Ky., and whose mines and mills are at Munday's Landing, in Mercer county, Ky., with shipping point at High Bridge, Ky.

Their product is obtained from a large calcite vein of hydrothermal origin, consisting almost entirely of crystallized calcite. This calcite is ground to an impalpable flour and bagged for shipment. The cost of mining the calcite, crushing and grinding the material to a mineral flour, are the causes of the cost of this calcium carbonate exceeding that of the limestone from Martinsburg, W. Va., or Bedford, Ind.

However, this source of lime is especially desirable in the manufacture of special grades of glass of the most perfect homogeneity, like optical glass. Incidentally, this mineral flour is also used in the rubber, whiting, filler, paint and insulating industries.

3. Burned or quick lime, CaO, which is manufactured by burning limestone in a lime kiln at a temperature of about 900 degrees Centigrade. The advantage of quick lime is that it saves heat in the furnace. The disadvantage is that it absorbs moisture and carbon dioxide from the atmosphere, and this variation in composition may lead to error in calculating the composition of the batch.

4. Slaked lime, $Ca(OH)_2$, is sometimes the form of lime used in mixing the batch. It is manufactured by adding water to quick lime. Its disadvantage is that it absorbs carbon dioxide from the atmosphere, thereby leading to the same possible source of error as in the case of burned lime.

5. Calcium in combination with fluorine as fluorite, CaF_2, and in bone ash as calcium phosphate, are added to produce translucent, opal and opaque white glasses.

SODIUM OXIDE, Na_2O.

Sodium in the form of sodium carbonate, Na_2CO_3, is added as a fluxing agent in the manufacture of nearly all forms of glass save lead flint glass, in which case the alkali present is potassium. Sodium may also be added in salt cake, Na_2SO_4, or sodium nitrate, $NaNO_3$, or sodium chloride, NaC1, or by the addition of mineral cryolite, $A1F_3$, 3NaF. The cryolite, however, is added more as an opacifier. All of these sodium compounds, save the mineral cryolite, are obtained from the various chemical manufacturers.

Neary all of the factories visited used sodium carbonate as a fluxing agent and as the source of the sodium in the glass. Several factories use the salt cake or sodium sulphate. Many plants use both.

Differences of opinion were expressed as to the relative advantage of soda ash and salt cake.

The advantages of using soda ash are: (1) It saves a large percentage in fuel used. (2) The furnace can be worked at a lower temperature. (3) The fining process proceeds more regularly. (4) There is no formation of glass gall. (5) The life of the furnace is longer.

The disadvantages are: (1) At a temperature of 1200 degrees Centigrade the glass is full of fine gas bubbles and seams. (2) The glass must be raised to a higher temperature until the product is quite liquid. (3) The heat is often turned off before the glass is perfect.

The advantages of the salt cake, Na_2SO_4,: (1) The product is cheaper. (2) The glass has a greater resistance to abrasion. (3) It has a higher melting point. (4) It has greater strength. (5) It contains fewer seeds. The disadvantages are: (1) It contains cords or waves at high temperatures. (2) It requires some reducing agent which must be carefully calculated.

If salt cake is used, then a certain amount of carbon in the form of coke, charcoal, anthracite, bituminous coal of high degree of purity should be used to enable the silica to decompose the sulphate. It is interesting to note here that one factory pulverized its forge coal and used it with success. When both sodium carbonate and sodium sulphate are used, a temperature of 1370 degrees Centigrade is required to decompose the salt cake and liberate the sulphur trioxide, SO_3.

POTASSIUM OXIDE, K_2O.

Potash is a necessary constituent of lead flint glass and of Bohemian glass. The former is a lead potassium glass and the latter a lime potassium glass.

The advantages of potash glass are: (1) Its greater brilliancy. (2) Its superior smoothness.

Its disadvantages are: (1) It is more expensive. (2) It requires a higher temperature to effect a clear melt or perfect fusion.

Potash is usually added to the batch in the form of the commercial salt potassium carbonate, K_2CO_3. Potassium nitrate, KNO_3, is a strong oxidizing agent and is sometimes added to glass. It is especially desirable in the manufacture of flint glass. To manufacture some special products orthoclase, K_2O, Al_2O_3, $6SiO_2$, is added.

If potash from feldspar is to be added in the manufacture of semi-transparent or translucent glass, or even vitrolite, it is essential that the mineral orthoclase be as rich as possible in its potash content. The analysis of the orthoclase as used is of interest here.

SiO_2	70.50
Fe_2O_3, Al_2O_3	17.00
K_2O	12.18
MgO	.0012
	99.6812

It is obvious that the sodium content of this feldspar must be very low.

If the potash is to be added in the manufacture of translucent glass, orthoclase cannot supply it all on account of the alumina and silica content of the feldspar. However, there is a saving in potash.

HISTORY OF ALKALIES.

In the early histroy of the glass industry the alkalies were derived from the ashes of the plants and sea weeds known as kelp, which was converted into a very impure carbonate. It is now manufactured on a large scale for the glass industry by treating sodium chloride with ammonium hydroxide and carbon dioxide under pressure. It must analyze 58 per cent sodium oxide, Na_2O.

The salt cake which is used in the manufacture of sheet glass and plate glass is made by the action of sulphuric acid upon common salt. The requirement of salt cake is that it must yield 97 per cent of anhydrous sodium sulphate and not more than 1 per cent of sodium chloride and sulphuric acid.

Potash was originally derived from the ashes of wood and other land plants. Now it is manufactured from a solution of potassium chloride being acted upon by ammonium hydroxide and carbon dioxide under pressure.

LITHIUM OXIDE, Li_2O.

Lithium belongs to the alkali group of metals. It is occasionally used in the manufacture of fine optical glass. Its source is from the mineral cryolite which is imported from Ivigtut, Greenland, or from the beautiful pink mineral, lepidolite, from California.

The analysis of the California lepidolite as given by B. F. Drakenfeld & Co., N. Y. City, is as follows:

SiO_2	50.37
Fe_2O_3	.05
Al_2O_3	23.35
CoO	1.33
MgO	.10
MnO	.46
Na_2O, K_2O, Li_2O	20.25
FI	1.31
Ignition loss	2.09
Moisture	.09
	99.40

BARIUM OXIDE, BaO.

Of the alkaline earth group, barium, strontium and magnesium remain to be considered.

Barium is often introduced in glass to give it weight. This is especially true of optical glass, table ware, lamp chimneys, etc. It may be added as the natural mineral, witherite, $BaCO_3$, or the precipitated barium carbonate, $BaCO_3$, or the nitrate, $Ba(NO_3)_2$, or the hydrate, $Ba(OH)_2$. Its advantages are: (1) It increases the specific gravity of the glass. (2) It imparts brilliancy to glass. (3) It increases the elasticity, tenacity and modulus of rupture. (4) It lowers the specific heat of glass. (5) It is less affected by the products of combustion than lead glass. (6) It can be melted in open pots or tanks.

Its disadvantages are: (1) It is more expensive than lime. (2) It causes the glass to show undesirable cords if care is not taken to avoid them. (3) It enables the glass to devitrify easily and rapidly. (4) It cannot be polished with hydrofluoric acid, HF.

STRONTIUM OXIDE SrO.

Strontium imparts no special properties to glass, and it is therefore seldom used.

MAGNESIUM OXIDE, MgO.

Magnesium is intentionally introduced in the manufacture of special glass. It is often added in the manufacture of common glass (1) as a minute impurity in the sand used. (2) As an impurity in the limestone used as fluxing materal. (3) As ground dolomite by some factories. (4) As the oxide from calcined magnesium carbonate. In ordinary glass it is regarded as an objectionable impurity.

LEAD OXIDE, PbO.

There are three metallic oxides that enter into the composition of glass designed for special purposes. They are the oxides of lead, aluminum and zinc. These will be discussed in the order of their group separation.

Lead oxide is an important constituent utilized in the manufacture of lead flint glass which is used extensively for high grade table ware and cut glass ware in general. The lead may be added either as litharge, PbO, or as red lead, Pb_3O_4. The latter is preferable because it is richer in its oxygen content. Metallic lead from which litharge, or red lead, is manufactured must be desilverized, and the oxide when used in the batch must be free from metallic lead, silver, copper and iron.

The advantages of the lead oxides are: (1) They fuse at low temperature and therefore serve as fluxing agents. (2) They are oxidizing agents and therefore create an oxygen atmosphere in the glass pot. (3) The resulting glass is softer than lime glass and therefore can be worked more easily. (4) Lead imparts greater density to the glass. (5) It gives a higher refractive index and

therefore greater brilliancy. (6) It is more resistant to chemical action.

Its disadvantage is that it may be reduced to metallic lead which tends to blacken the glass. To avoid this possible reduction all reducing gases must be kept away from the molten glass.

ALUMINUM OXIDE, Al_2O_3.

Alumina is added to the batch both intentionally and accidentally. In the latter case it is introduced through the minute impurities in the sand used as a glass sand. These aluminum bearing impurities may be cleyey matter essentially kaolinite, or orthoclase, albite, oligiclase, muscovite, biotite. The most of the kaolinite and the micas may be removed by washing the sand, but the unkaolinized feldspars remain as sand grains in the glass sand.

Aluminum is also added as an impurity in the limestones used as a flux in the fusion of the batch. It is most likely to occur in the limestone as minute particles of clayey matter. In the factories visited there seemed a difference of opinion regarding its effect upon the commercial value of glass sands. Some manufacturers would place the maximum aluminum content permissible in the sand as 0.2 per cent, regarding the alumina nearly as objectionable as iron oxide. Others would permit the alumina content of sands to reach 4 or 5 per cent.

Alumina is intentionaly added to a glass batch: (1) As a feldspar, either the natural minerals, orthoclase or albite. (2) As the mineral cryolite, AlF_3, 3NaF, which is used as an opacifier. (3) As the mineral kaolinite, $2H_2O$, Al_2O_3, $2SiO_2$, or as china clay.

As the analysis of orthaclase has already been given, it need not be repeated here,, but the analysis of china clay as used by one factory is of interest.

SiO_2	47.30
Al_2O_3	47.00
Fe_2O_3	tr
CaO	——
MgO	——
H_2O	4.70
	99.00

The analysis of the mineral cryolite from Ivigtut, Greenland, as given by the same company is:

SiO_2	——
Al_2O_3	13.00
Fe_2O_3	——
Na_2O	32.80
FG	54.00

The advantages of alumina are: (1) It reduces the tendency of glass to devitrify. (2) It enables glass to be repeatedly melted and blown without change in its composition. (3) It decreases the solubility of glass in water and weak acids. (4) It increases the surface tension of glass when it is rapidly chilled. (5) It can be easily molded into shape in a molding machine. (6) It shows little tendency to be filled with minute seeds. (7) It increases the tenacity of glass. (8) It increases the resistance to abrasion. (9) It adds brilliancy to glass. (10) It is less susceptible to the carbonizing and reducing agents of the fuels used.

Its disadvantages are: (1) It demands a higher temperature, for alumina is a very refractory oxide. (2) It retards the volatilization of the alkalies at the surface of the glass. (3) It decreases the fusibility of the glass. (4) It does not mix well with other kinds of glass to form a perfectly homogeneous product.

ZINC OXIDE, ZnO.

The oxide of zinc is occasionally used in the manufacture of optical and heat resisting glass. It is added as the oxide, ZnO.

The advantages of zinc in glass are: (1) It imparts brilliancy to the glass. (2) It renders it more tenacious. (3) It increases its compressive strength. (4) It makes it more resistant to the corrosive acids. (5) It imparts a high fluidity to the glass.

Its disadvantages are: (1) The losses due to volatilizing action are apt to be high. (2) It renders the glass more devitrifiable.

CHAPTER VIII.

COLORIZERS AND DECOLORIZERS.

In the preparation of this chapter on colorizers and decolorizers the author is largely indebted to Charles R. Fettke for his work on Glass Manufacture and the Glass Sand Industry of Pennsylvania, pp. 82-90. The color in glass may be introduced either by colored compounds in a state of solution in the glass, or by the optical effect of minute particles held in suspension by the glass.

COLORIZERS.

MANGANESE DIOXIDE, MnO_2.

Pyrolusite, or the black oxide of manganese, will produce a range of colors varying from amethyst to violet. In lime potash glass manganese producs an amethystine color, while with lime soda or lead flint glass the color is reddish violet.

Manganese and iron together will produce amber and brown colored glasses. Manganese and cobalt together will improve the violet color. An excess of manganese alone will produce a jet black. Before the war the most of the manganese used in America in the glass industry came from the Caucasian mountains. Now a part of the manganese dioxide is obtained from the high grade deposits of pyrolusite in California, a part from the artificial black oxide of manganese, and a part from high grade rhodochrosite, $MnCO_3$.

NICKEL OXIDE, NiO.

Nickel oxide produces an amethyst color in lime potash glass, a reddish brown color in lime soda glass, and a purple color in lead glass. As in the case of manganese, cobalt added with the nickel will improve the violet color.

COBALT OXIDE, CoO.

Cobalt enters into the composition of all varieties of blue glass. It is a strong coloring agent, and the color is little affected either by the composition of the glass or the state of oxidation of the metal. In the case of lime potash and lime soda glasses the color is a violet blue, while with lead it is a spectrum blue. Cobalt is added as zaffre, as potters blue, and as cullet from smalt blue glass.

COPPER OXIDE, CuO.

Under oxidizing conditions copper oxide produces a pale blue in glass by the formation of a cupric silicate which is soluble in the

glass. In the case of lime soda glass the color is a greenish blue. In lead glasses it produces a green color. Under reducing conditions, copper oxide imparts a red color to glass.

FERROUS OXIDE, FeO.

Iron, as has been previously noted, is one of the most dreaded constituents in glass sands. Ferrous iron imparts to lime potash glass a greenish blue tint, to lime soda glass a bluish green tint, and to a lead glass a yellowish green color. The iron unites with the silica in the formation of a ferrous silicate which is soluble in the glass.

CHROMIC OXIDE, Cr_2O_3.

Chromic oxide is quite extensively used in the manufacture of colored glass. To a lime potash glass it imparts a yellowish green color, to a lime soda glass a grass green color, and to a lead glass a reddish green color.

Chronium is never added to the batch as the mineral chromite, Cr_2O_3, FeO, for this mineral would introduce too much iron in the glass. It is added, however, as chromic oxide, Cr_2O_3, as potassium chromate, K_2CrO_4, as potassium dichromate, $K_2Cr_2O_7$, as lead chromate, $PbCrO_4$, and as barium chromate, $BaCrO_4$. The solution of the chromium in the glass is most easily affected in the case of the dichromate.

FERRIC OXIDE, Fe_2O_3.

Ferric iron imparts to a lime potash glass a yellowish green tint, to a soda lime glass a greenish yellow tint, and to a lead glass a yellow-green tint.

CERIUM OXIDE, CeO_2.

Cerium oxide effects a yellow color in glass.

URANIUM OXIDE, UO_3.

To a lime soda glass uranium imparts a yellowish green color, whose fluorescence cannot be compared in beauty with the yellow fluorescent color imparted by uranium to a lime potash glass. According to S. P. Kenny, superintendent of one of the factories visited, if salt cake, Na_2SO_4, is omitted in the batch and uranium is added, any color from ruby thru green to yellow can be produced.

GOLD, Au.

The precious metal, gold, is sometimes used to produce a brilliant ruby tint in glass. To effect this color it is necessary to reheat the glass and allow it to cool slowly, then a rich rose ruby tint is produced.

SILVER, Ag.

The precious metal, silver, imparts to a lime potash glass an orange yellow color, and to lime soda and lead glasses a deep yellow color. The yellow color is due to a collodial suspension of fine particles of silver which transmit yellow light.

SELENIUM, Se.

The rare element, selenium, imparts to barium glass a pink or pale rose red color.

DECOLORIZERS.

MANGANESE DIOXIDE, MnO_2.

From the earliest inception of the glass industry the mineral pyrolusite, MnO_2, has been utilized to wash out the color imparted by iron oxides to glass. Its use is said to antedate the Christian era.

When manganese and iron oxides are both present in the batch, the colors normally produced by either metallic oxide are neutralized, and the glass appears colorless. The pyrolusite used needs frequent and careful analysis, for it is a mineral that often has a part of its manganese replaced by iron.

When manganese dioxide is added to the batch in the absence of other coloring compounds a pinkish purple or violet color results. The exact color produced will depend: (1) Upon the composition of the glass. (2) Upon the temperature of the fining process. (3) Upon the duration of the fining process. (4) Upon the reducing or oxidizing agents in the furnace. (5) Upon the quantity of manganese dioxide used, for an excess of pyrolusite will produce a jet black color.

Manganese dioxide cannot be added to the molten glass to control color, for its high specific gravity carries it to the bottom of the furnace. Therefore it must be uniformly mixed with the other constituents before the batch is fed into the furnace. Furthermore, manganese glass needs to be slightly pink in color before annealing, for it is decolorized somewhat during the process of annealing.

NICKEL OXIDE, NiO.

When nickel oxide is used as a decolorizer with sodium and potassium glasses a greenish brown tint is usually produced. With lead glass nickel oxide cannot be used as a decolorizer for when nickel is used in the manufacture of a lead glass, the color produced is purple.

SELENIUM, Se.

The rare element, selenium, is quite generally used as a decolorizer to counteract the colors imparted to glass by iron oxides. It is especially satisfactory in lime potash glasses and in glasses containing a barium base. It is fairly satisfactory with a lime soda glass, but it cannot be used with a lead glass on account of its tendency to form an artificial clausthalite, PbSe, in the glass.

CHAPTER IX.

COMPOSITION OF THE BATCH.

The batch is the mixture of the raw materials that enter into the furnace for the manufacture of glass. More than 50 per cent of the batch is composed of silica, but the percentage may vary somewhat with the kind of glass desired. A little silica may be added thru the presence of impurities in both the sand and the fluxing limestone. The silica content of the glass is increased above that of the batch by the liberation of volatile gases, carbon dioxide, CO_2, and sulphur trioxide, SO_3.

From the standpoint of bulk, at least, the sand is the most important constituent, and its kind and proportions influence in a large measure the character of the glass obtained. The sand is largely responsible for the transparency, brilliancy and hardness of the glass. Pure sand produces a colorless glass. The quality of the glass is determined largely by the quality of the sand used. For the manufacture of the finest flint glass which is used for cut glass, stem ware, vases, optical glass, etc., only the purest sand can be employed. Such high grade glass must possess perfect transparency, uniform density and great brilliancy. Small percentages of iron tend to color the glass and alumina produces cloudiness in the ware.

The more common forms of glass like bottles, jars and rough structural work, can be made from sands containing a much higher percentage of impurities than those required for the manufacture of glass noted for its transparency and water whiteness. Magnesia which may be introduced into the batch either as an impurity in the sand or the limestone is highly refractory and renders the batch less fusible.

Reasonably pure sands may be obtained both from unconsolidated sand deposits or sandstones themselves. In the latter case the sandstones should be sufficiently friable to be easily crushed, and the grains uniform in size, angular or sub-angular in form.

The composition of the batch, as given by one factory visited, and used in the manufacture of lead blown table ware of great beauty, is as follows:

Sand, SiO_2	100x15
Soda ash, Na_2CO_3	23x15
Red lead, Pb_3O_4	28x15
Lime, CaO	8x15
Soda niter, $NaNO_3$	9x15
Manganese dioxide, MnO_2	1¾
White arsenic, As_2O_3	5½ to 6
Potters blue	1oz

Smalt blue cullet may also be added to the batch.

An excellent batch for a potassium lead flint glass will be of interest:

Quartz sand, SiO_2	100x15
Red lead, Pb_3O_4	30x15
Potassium carbonate, K_2CO_3	22x15
Soda ash, Na_2SO_4	13x15
Soda niter, $NaNO_3$	9x15
Manganese dioxide, MnO_2	1¾
White arsenic, As_2O_3	5.5 to 6
Potters blue	1 oz.

Smalt blue cullet may also be added.

Prof. Charles R. Fettke in his work on Glass Manufacture and the Glass Sand Industry of Pennsylvania, on pages 90-92, has carefully compiled the composition of 53 batches of American, English, French and German glasses, which will be of special interest to both American and foreign manufacturers.

MIXING THE BATCH.

It is absolutely essential that the batch be intimately and thoroughly mixed before it is fed into the furnace. To accomplish this the smaller factories have large wooden bins or boxes in which the materials after they have been weighed out are carefully shoveled over and over again. The mixings are then screened to a proper size to prevent the feeding of lumps into the furnace.

In the larger and better factories the batch is mixed by machinery. The work is more perfectly executed, and the resulting glassware better. Cullet is also added, for the presence of cullet in the furnace seems absolutely essential to the manufacture of good glass.

CHAPTER X.

SELECTION AND PREPARATION OF SAND.

It has already been noted that sands suitable for the manufacture of a given type of glass ware may prove entirely unsatisfactory for another grade of glass. A mere field examination is insufficient, even tho it is exceedingly essential.

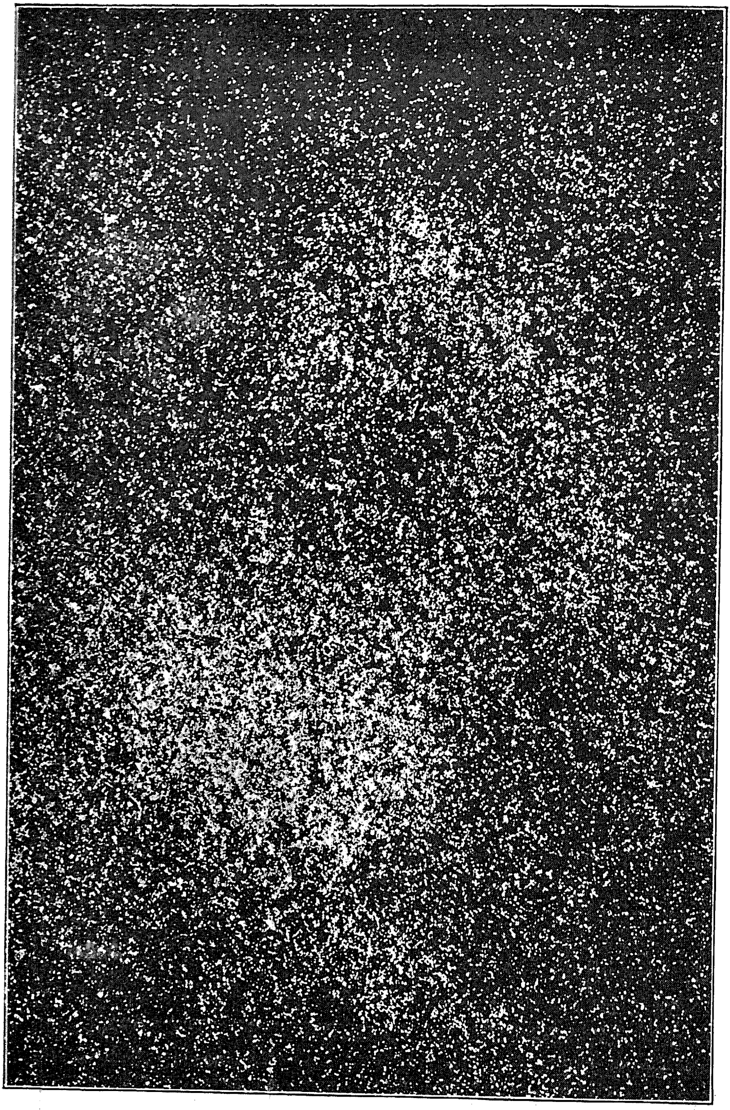
Certain rules are here given for field examinations which if carefully followed will prove advantageous: (1) Examine many samples with a triple magnifier or an aplanatic lens. This will reveal the presence of many objectionable impurities, as feldspar grains, scales of mica, sulphides of iron, coatings of calcium carbonate, clayey and organic matter, and if the sands are derived from the disintegration of sandstones associated with coal formation, fine grains of coal. If any of these are present in very appreciable quantity, the sand should be rejected at once. (2) The sand should be white or nearly white in color, for yellowish and reddish sands are apt to contain too large an iron content. They may, however, be suitable for molding sands. (3) The sand should be of uniform size and medium fineness. If it contains much material that will not pass a 20 mesh sieve the grading of the sand becomes too expensive. If the material passes a 120 mesh sieve it will burn out in the batch, or sink to the bottom of the furnace. (4) The sand should be angular or subangular, for such sands fuse more readily in the furnace than well rounded sand. As has been previously noted, the fusion begins upon the edges of the sand grains. The deposit must be sufficiently large to asure a daily output of 100 tons or more for many years. Many factories use 2 car loads or more of sand each day in their furnaces. (5) The sand should be free from flint or chert pebbles, for these are highly refractory and give rise to stones in the glass. (6) Average samples, not carefully selected ones, should be secured for both a qualitative and a quantative chemical analysis. For these analyses several pounds of the material from various exposures of the sand should be collected and intimately mixed.

The final conclusion as to the commercial value of the sand cannot be drawn until these analyses have been made.

MINING OR QUARRYING.

If the sands are unconsolidated land sands of pure white color, and free from all objectionable impurities, they may be mined directly with scoop shovels and loaded into cars for shipment to the glass factories. Yet even here it is better to wash the sand.

If the sands are river deposits beneath the surface of the stream like those of the Ohio river and parts of the Big Sandy valley, they



(1.) Olive Hill glass sand grains showing exact size.

may be pumped directly from the bed of the stream by big suction pumps and conveyed to washers. They are partially washed by the pumping process. Often these sands have been catalogued as washed sands.

If the sand is a loosely cohering sandstone sufficiently soft and friable to be broken up with a strong hydraulic jet, as at Tip Top, Kentucky, then the sand may be pumped direct to washers. The more consolidated sandstones like those in the Olive Hill District in the eastern part of Kentucky must be broken down with explosives and crushed before washing.

All deposits other than those in the beds of rivers have a mantle of residual soil covering them. This mantle is stained yellowish brown, brown, reddish brown, or red, according to the amount of iron oxides it contains and their degree of hydration. Such soils need to be carefully removed from the underlying glass sand, for its mixture with the sand will render the sand worthless for the manufacture of glass.

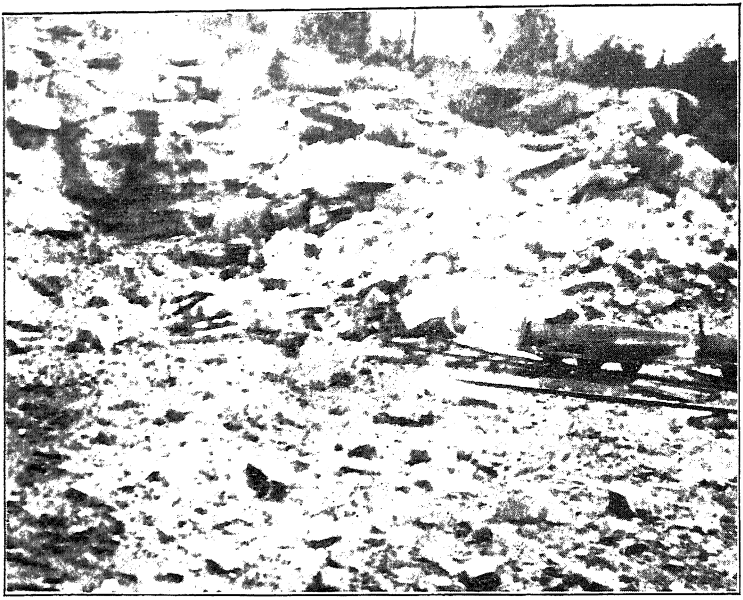
In Kentucky, at least, there is sometimes a zone of iron stained sand superimposed upon the white glass sand which needs to be carefully separated from the blocks of white or yellowish white glass sand, that the resulting white glass sand may not be too rich in its iron content. This zone varies from 1 to 25 feet in the possible quarries visited. This sand should be crushed separately from the glass sand and used as a molding sand, for which there is a ready and waiting market. Too much care cannot be exercised in the selection of only the white sands for glass manufacture.

CRUSHING THE SAND.

Loosely cohering consolidated sandstones may be crushed in an ordinary 8 foot wet pan under rotating heavy wheels or mullers, similar in construction to those used in potteries or sewer pipe plants. The crushed sandstone, together with its impurities, is conveyed with water into a circular riddle or screen of 16 mesh, and then thru a second similar screen. The coarsely screened sand is carried by a trough containing a large supply of water into the washing department.

The more compact sandstones may be crushed in a Blake jaw crucher or a gyrating crusher into fragments varying from a fraction of an inch up to 2 inches. In either case the sand passes from the crusher into a chaser mill. A Jeffrey pulverizer may be substituted for either of the above types of crushers, but the Blake jaw crusher is preferable.

Sandstones, if sufficiently friable, may be crushed in a Potomac Pulverizing mill. A single tube is 24 feet in length, 6 feet in diametor, and is filled 1-3 full of flint pebbles. The sand conveyed to the tube is ground or pulverized by the action of the pebbles in the rotating cylinder. The mill is lined with silica brick and lasts about



(2.) Glass sand quarry of the Camp Glass Company, Lawton, Carter County, Kentucky.

10 months. Not only the sand, but also the lining of the mill and the pebbles within the mill, are reduced ultimately to a rock flour.

Since the lining of the tube consists of silica blocks, and the flint pebbles are very pure silica, the wearing away of these materials does not introduce an impurity into the glass sand. If the sand thus pulverized passes screens varying from 40 to 80 mesh it would be of suitable fineness for glass sand.

The rock flour which passes a mesh from 110 to 130 would be too fine for use in the manufacture of glass, but it could be utilized as a paint, for scouring and polishing powders, and as an adulterant of soap.

CHASER MILL.

A chaser mill consists of a circular steel tank or pan, varying in diameter from 6 to 9 feet, in which two heavy steel rollers or mullers revolve. The pan itself is stationary. The heavy wheels chase each other around in the pan, hence the name, chaser mill. Water is fed into the crushed sand and the sand is delivered from the chaser thru screens on the side of the pan.

The capacity of a mill depends somewhat upon the number of crushers and chasers it contains, but a 9 foot chaser should easily prepare for washing 200 tons of sand per day.

REVOLVING SCREENS.

From the chaser the sand goes to a revolving screen. The screen consists of 10 to 12 mesh brass wire. The fine material passes thru the screen to the washer, while the coarser material is returned to the chaser for further treatment.

WASHING THE SAND.

Some producers dispense with the operation of washing their sand. Washing improves the quality of the sand to the highest grade possible. It is a mistaken economy to neglect this important phase of treatment, for the price of sand, and use or rejectment, is affected by the small percentage of impurities that may be washed away.

Where sandstones are so loose and friable that they may be broken down by a strong hydraulic jet, the sand and water are pumped into a set of bins so that the sand may settle quickly, while the finer impurities are washed away.

A second method of washing sand consists of an open top pug mill in which rotating augers or screws move the sand up inclined troughs, rolling it over and over, so that by attrition the sand is freed from a large percentage of its impurities and stains. The impurites are readily removed by a stream of water playing down the trough. The troughs are inclined at angles varying from 18 to 20 degrees. The sand is fed into the trough from the foot and the water from the head. The washer will require from 200 to 300 gallons of water per minute, therefore an adequate supply of water is absolutely essential in washing sand in an auger washery.

At Tip Top, Hardin county, Kentucky, 28 miles southwest of Louisville, the hydraulic method as employed at Ottawa, Illinois, is used to remove the sand from the pit. A jet of water from the nozel of a large hose is sufficient to break down the sand, free it from any interbedded clay, and wash it into the sump of a Nye pump at the lowest point in the pit. The pump raises the sand 12 feet to a screen having 1-8 inch meshes. The screened sand drops thru a chute into a tank, from which it is raised by a gently inclined elevator out of the pit into a set of wash bins.

The washers consist of 2 sets of wash bins, 2 bins each. The bins of the first set hold 25 tons. The bins of second set hold 40 tons each. A second elevator carries the sand to the second set of bins, from which a second Nye pump removes the sand to the third set of bins. The sand is washed out of the third set of bins by another vacuum pump and delivered into the drain bins.

DRAINING BINS.

Some producers do not dry their sand. If the sand is to be shipped wet to the factories, it is now ready for shipment. Sand should be thoroughly dried for two reasons: (1) Wet sand does

not mix readily in the batch. (2) It adds too much water to the contents of the furnace.

The drain bins serve two purposes: (1) They permit a part of the water to drain out of the sand. (2) They are used for storage purposes, and are often connected with a railroad spur. At Tip Top, Kentucky, the spur is only 500 feet in length, and at East View, Kentucky, there is only a siding. At Tip Top there are three bins of 50 tons capacity, and three bins of 40 tons capacity, making convenient measures for loading the cars. Cinders are used to insure rapid drying.

The water from the washing bins and the drain bins may be conducted into a settling tank, and when clarified of its sediment it is conducted into a storage tank and used again. It must, however, be borne in mind that the water must be clean before it is reused, or else clayey matter will be reintroduced into the sand. This requirement is just as essential as the requisite that the first wash water must be clean.

DRYING THE SAND.

The dryer at Tip Top, Kentucky, consists of a rotary cyinder 40 feet in length and 6 feet in diameter, with fire heat passing thru the cylinder. Sand is sometimes dried in a steam dryer with 7,000 feet of heating surface and a capacity of 100 tons per day of 10 hours.

Steam dryers are rapidly replacing heat dryers. They are built in sections 25 feet in length, 8 feet in width, and 6 feet in height. The bottom of the dryers is hopper shaped and the walls are built of common brick. Inside the dryers there are horizontal steam pipes resting on inverted angle irons. These pipes are arranged in tiers, one above the other, and placed closer together towards the bottom of the dryer. The sand is delivered to the top of the dryer by a belt conveyor, and removed from the bottom of the dryer by a second belt conveyor. The heat from the steam pipes evaporates the moisture from the sand. Exhaust fans remove the steam and damp air which accumulates under the angle irons.

It was suggested at one plant manufacturing brick that an economical method of drying the sand would be to use shallow pans about 30 feet in length, 6 feet in width, and resting upon a network of steam pipes, such as are used in drying brick. The drying pans would be moved thru the drying house by machinery. This suggeston implies that the dried sand would be removed from the pans by hand, and therefore the process would be applicable only on a small scale.

The cost of operating a steam dryer is said to be less than that of a heat dryer. Three classes of dryers are in general use: (1) Rotary cylinders thru which the sand passes against a draft of flame and hot gas. (2) A stationary roaster. (3) Coils of steam pipes.

SCREENING THE SAND.

Some producers do not screen the dry sands, but carry it from the dryer in a cup elevator to the storage bins, from which it is loaded direct into cars for shipment.

The screening of the sand is essential to the preparation of the best sand for the manufacture of glass, for uniformity of size of the individual grains is one of the requisites of good glass sand. Fettke states that 18 meshes per inch is probably the most common size used. As already noted, coarse sands are difficult to fuse in the furnace, and sands which pass 110-130 mesh burn out in the batch.

Sand which passes thru a 60 mesh sieve is classified as fine grained; 30 to 40 mesh sieve as medium grained; 20 to 30 mesh sieve as coarse grained. These divisions are made for the purpose of classifying glass sands according to the size of the individual grains.

STORAGE BINS.

After the dry screening the sand is elevated to the storage bins, ready for shipment to the glass factories. These storage bins usually consist of a series of bins of 40 to 50 tons capacity, which make convenient measures for loading the cars.

In some instances, as at Lawton, Kentucky, the sand is conducted into one open bin of hundreds, if not thousands, of tons capacity. The open bin permits the addition of impurities to washed and dried sands by the soot and cinders from the plant and by wind blown dust. It is preferable that bins for the storage of sand be covered.

SHIPPING THE SAND.

Sand is shipped to the various factories: (1) In bags of convenient size for handling. (2) In closed flat-bottomed cars, which may or may not be lined with paper. (3) In open flat-bottomed cars. (4) In open V-shaped cars. It is preferable that the sand be shipped in closed cars to prevent the addition of impurities while in transit.

SUMMARY.

The complete process of preparation of glass sands includes mining or quarrying, breaking, crushing, grinding into component grains, screening, washing, draining, drying, screening to various sizes the dry sand, and storage.

CHAPTER XI.

TYPES OF FURNACES.

The type of furnace used in the manufacture of glass depends in part upon the kind of glass desired and in part upon the general equipment of the factory. Certain kinds of glass can be manufactured only in furnaces of a definite type.

Two main types of furnaces are in general use in the glass industry, each of which may be subdivided into two sub-types. The main types are: (1) Pot furnaces. (2) Tank furnaces. The subdivisions of the pot furnaces are: (1) Open pot furnaces. (2) Covered pot furnaces. The subdivisons of the tank furnaces are: (1) Continuous tank furnace. (2) Intermittent tank furnace.

POT FURNACES.

The open pot furnace which is used in the manufacture of plate glass is rectangular in shape. The larger furnaces are about 50 feet in length, 12 feet in width, and 5 feet in height on the inside. These furnaces contain 10, 12, 14, 16, 18, or 20 pots arranged with an equal number on each side. Each individual pot weighs from 1 to 2 tons. The temperature required for the complete fusion of the batch in the open pot furnace ranges from 1,450 degrees C. to 1,540 degrees C., or 2,650 degrees F. to 2,800 degrees F. The life of the individual pot is only a few months on account of the hard usage required. The furnaces are so constructed that any given pot may be replaced at any given time.

The covered pot furnace is used in the manufacture of lead glasses. They are very similar in shape to the open pots, and the materials of which they are made may be mixed in slightly different proportions. This is necessary on account of the variations in the composition of batch required in the manufacture of plate glass and lead glass.

The pots for the pot furnace must be made from highly refractory clay. The fusion point of such clay must not be less than 1,690 degrees C. or 3,074 degrees F. This degree of refractoriness is required that the pots may withstand the highest heat of the furnace. The requirements of glass pot clays are: (1) A refractoriness that will withstand the highest temperature of the furnace without showing any material change. (2) A plasticity that will permit the addition of 50 or 60 per cent of grog without being materially affected. (3) The clay must burn dense at as low temperature as possible. (4) The clay products must resist the solvent action of the molten glass as far as possible, otherwise undesirable colors may be obtained in the glass. (5) The clays used must possess a low air shrinkage and a low fire shrinkage. (6) The clay must impart toughness to the finished product. (7) The clay must be aluminous, for aluminous clays stop pit-

ting at high temperatures, while a siliceous clay will cause pitting at high temperatures. High temperatures short of softening are not considered detrimental to glass pots, while sudden temperature changes will cause cracks to appear.

The batch itself may cause cracking in the pot, and to overcome this tendency thinner glass pots are now being used. The holes sometimes observed in glass pots result largely from the presence of sulphides of iron in the clays utilized. The bottom of the pot will not resist the solvent action of the molten glass as well as the sides. The corrosive agents are under greater pressure at the bottom than on the sides, for the pot furnace must retain one or more tons of molten metal all the time, whose ingredients are powerful fluxing agents. The furnaces are also subjected to great strain thru the unequal contraction due to sudden cooling by the addition of new batches.

The presence of the mineral sillimanite is due to the combination of the alumina in the glass pot and silica at high temperatures, and is always formed when the molten glass comes into contact with the clay. Sillimanite may therefore be termed a mineralogical pyrometer, for it cannot be formed at a temperature below 1,300 degrees C. When the temperature rises above 1,400 degrees Centigrade it is natural to expect the formation of such minerals as sillimanite and tridymite.

The conversion of quartz into tridymite is accompanied by an expansion which corresponds with a change in specific gravity from 2.65, that of quartz, to 2.33, that of tridymite. This expansion may cause bulging or spalling of the glass pots.

TANK FURNACES.

Continuous tanks are now extensively used in the manufacture of window glass. The floor and walls of the tank are covered with highly refractory fire clay blocks. These blocks demand the same requirement in the clay as are given earlier in this chapter for glass pots. If these conditions are not observed cracks will occur in the furnace and undesirable constituents will enter into the glass. The furnace is covered with an arch of silica brick which are capable of withstanding high temperatures, and are of great mechanical strength. They must not come in contact with the molten glass, for the constituents of the metal possess powerful corrosive agents.

It was the author's privilege to thoroughly examine, last June, a 750 ton continuous tank furnace which was in the process of reconstruction. This furnace was 85 feet in length, 28 feet in breadth, and 5.5 feet in depth. It was divided into three compartments known as: (1) The charging chamber. (2) The refining chamber. (3) The working chamber. The charging chamber is 45 feet in length and 28 feet in width. Into the forward end of this chamber

the batch and cullet are fed. It contains 24 gas burners, 12 on either side, and the temperature required for the fusion of the batch falls between 2,600 and 3,000 degrees F.

The refining chamber, or neck of the furnace, is 15 feet in length and 18 feet in width. The neck contains 4 scum holes, two on either side, thru which the scum gathered by the floaters is removed. It contained an extra bridge for gathering any refuse that was not collected by the floaters.

The working end or nose of the furnace is somewhat semicircular in form and 20 feet in length. It contained 20 gathering cups. These gathering cups are made of the same refractory clay as the blocks on the floor and situated directly back of the gathering holes, thru which the workmen remove the molten glass. The glass has to pass beneath the cups to fill them, so that any refuse not gathered by the floaters and bridges may not enter the glass. Larger continuous tanks than the one described are in use. They are sometimes 100 feet in length, 30 feet in width, and 6 feet in depth, and contain 1,000 tons of molten glass.

In the case of intermittent tanks the batch is fed into the charging chamber and the wash holes are closed. When the glass is thoroughly fused and the surface shows no gas bubbles the temperature is allowed to fall until the glass reaches the right viscosity. The work holes are then opened and the glass is manufactured. Intermittent tanks are usually filled in the afternoon and the glass worked on the following day. They are therefore often called day tanks. They are wasteful of heat, and their use should be discouraged.

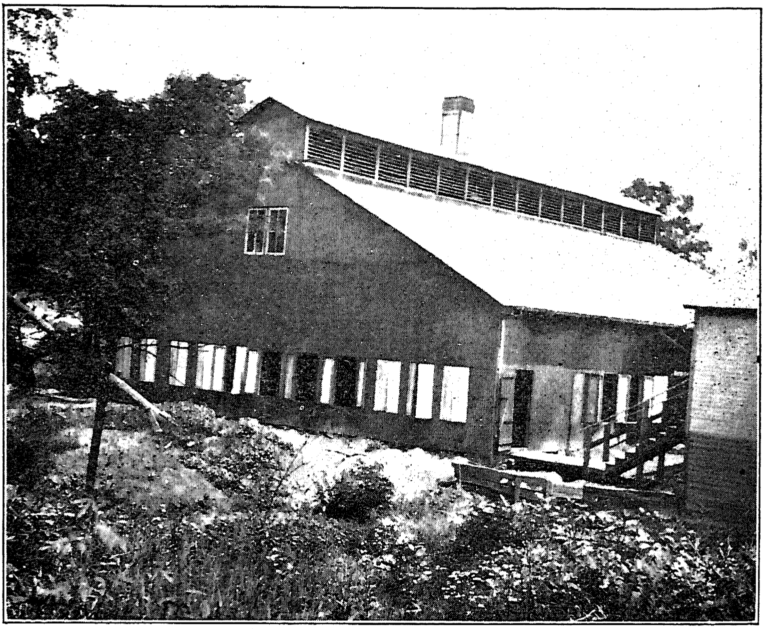
CHAPTOR XII.

PROCESSES OF MANUFACTURE.

When molten glass has reached the proper degree of viscosity it may be worked or fashioned into any form desired, provided the workman has sufficient skill in his manipulation.

Three general methods are in use in the conversion of glass into its desired form: (1) By blowing. (2) By pressing. (3) By casting.

Many different forms of glass are manufactured by varied methods, and the more important of these will be tersely described.



(3.) Glass Factory of the West Virginia Glass Company, Star City, W. Va.

WINDOW GLASS.

Formerly all window glass was manufactured by hand. The process required of the workmen great strength and skill. A few plants visited still continue to use the hand blown method. Most of the factories now manufacture machine made window glass. This method only will be described.

When the batch in the working end of the furnace has the proper viscosity, several men operating a large ladle, with handle some 15 feet in length, gather from the nose of the furnace several hundred pounds of molten metal. After slowly swinging the ladle around it comes directly over a rather shallow clay pot into which it is emptied. The pot is made double and as soon as emptied by drawing a cylinder of glass, the pot is inverted so that the residue of viscous glass may drain out while the other end of the double pot is being filled and the cylinder of glass drawn. The largest cylinder seen drawn by the author was 48 feet in length and 28 inches in diameter. The normal diameter is 24 inches.

In the drawing of the cylinder a bait is lowered into the glass. The bait consists of two metallic discs with a hole some two inches in diameter in the center and the lower disc grooved so that the glass may secure a strong hold upon the bait by solidifying around the bait. The bait is then slowly raised. The first two feet of glass wll be funnel-shaped. Then the cylinder will be perfect for 48 feet. The perfectness of the cylinder, however, will be determined: (1) By the rapidity with which the cylinder is drawn. (2) By the temperature of the glass itself. (3) By the pressure of the air blown into the cylinder. (4) By the pressure of the surrounding atmosphere. If these conditions are not properly adjusted, then the cylinder will have constrictions that may deepen into V-shaped indentations, and the glass only fit for cullet.

When the cylinder has reached its full length of 48 feet, the bottom is cut off by a cold piece of metal, the fracture following around the cylinder from the place of contact with the metal.

A hoop is then placed around the lower end of the cylinder and by pulling steadily and controlling the drop the cylinder is lowered into a wooden form with arms curved upwards. The cylinder is then cut into the desired length of 48 or 60 inches by electrically heated wire wound around the cylinder. After the cylinder has been cut into the desired lengths sawdust is spread over the lower part of the inside of the cylinder and a heated piece of steel moved forwards and backwards causes the glass to fracture in a straight line for its entire length. One end of the upper surface is cut with a diamond to a depth of about an inch and then by two men gently bending the glass downwards the glass breaks into two semi-circular sheets.

The half cylinders of glass are taken to the flattening oven, which contains large flat blocks of fire clay upon which the glass is placed with the convex side down. The high temperature of the oven causes the glass to flatten out into a sheet, but to make the surface perfectly smooth it is rubbed over with a basswood block attached to a long handle. The process is continued until the surface of the glass is perfectly clear, then the blocks in the oven turn around slowly and the glass is placed on the rods of the annealing oven, where it is slowly cooled. When the glass is annealed it is removed from the lehr

and immersed in a bath of hot dilute hydrochloric acid, HCl. When removed from this bath the glass goes to the cutters, who trim the glass to the desired dimensions, and then to the boxers, who prepare it for shipment.

CROWN GLASS.

Crown glass received its name from the form or manner in which it is fashioned. It was once a favorite for window panes, but now it is of minor significance and manufactured for ornamental work only. The panes are much more brilliant than window glass and of tapering thickness.

The molten glass is gathered in the same manner as for hand blown window glass and rolled into a globe on a marver. This process of manipulation is to make the glass of uniform consistency.

The skilled workman blows the glass into a sphere, then he flattens the under side of the sphere keeping the bullion point, or thick apex of the original cone. While the first workman rests his blowpipe on a support, a second workman with a punty, or solid iron rod, attaches a small cup of warm glass to the bullion point. The blower detaches his blowpipe by touching the neck of the flattened globe with a piece of cold iron and quickly striking it a gentle blow. The punty man carries the globe away and reheats it in another furnace. The opening in the glass where it was removed from the blowpipe is enlarged until the glass assumes the appearance of a crown. Then the workman whirls it out into a flat disc or table. The glass is kept revolving until it becomes cool enough to be laid on a support. Here it is clipped from the iron rod of the punty workman and sent to the annealing oven. The diameter of the glass table may be as great as 6 feet. After it is thoroughly annealed the glass is sent to the cutting room, where it is usually cut into small square panes for decorative purposes. The bullion point itself is sometimes used as a means of decoration.

PLATE GLASS.

Plate glass is of two different types: (1) Rolled plate glass. (2) Polished plate glass. Rolled plate glass is manufactured by being rolled out into a sheet on a metal plate by heavy iron rollers. The batch is fused in a continuous tank furnace. The molten glass is gathered from the furnace by means of an iron ladle. The size of the ladle will depend somewhat on the size of the plate glass desired. For the large sheets 200 pounds of glass is sometimes required.

The ladle is emptied upon an iron table and a machine driven heavy iron roller passes over the molten glass, pressing it into the desired thickness. When the glass has cooled sufficiently to be safely handled, it is drawn off the iron table and placed upon a stone table. It is then transferred to the annealing lehr and properly annealed. Then it is taken to the cutting room, where it is trimmed, sorted, and packed for shipment. Rolled glass is used largely for skylights.

The batch for polished plate glass is fused in large open glass pots. These pots vary in diameter from 38 to 52 inches. The larger pots will weigh more than a ton and will contain 2,800 pounds of molten glass. Since minute defects are plainly visible in polished plate glass, on account of its superior thickness, great care must be taken that the batch is perfectly melted and fused.

When the fining process is complete the pot is lifted from the furnace and carried by means of a crane to the casting table. All glass gall must be skimmed from the pot before it is emptied upon the table. As soon as the pot is emptied it is returned to the furnace to prevent further cooling.

As soon as the glass has been poured upon the flat iron table a heavy machine driven iron roller passes over it and the glass is pressed to the required thickness. The plate glass is now quickly transferred to the annealing oven which for plate glass is usually a continuous lehr.

After the plate glass has been properly annealed it goes to the cutting room for trimming off the cullet. The plates are now ready for grinding. The plates are carefully set in plaster of paris tables and first ground down with sharp sand. Coarse sand is first used and then fine sand. It is then ground with fine emery. After both sides of the glass have been ground perfectly smooth the plate glass is transferred to another table, where it is buffed with felt buffers using rouge which consists of ferric oxide, Fe_2O_3, reduced to an impalpable powder. When the buffing has been completed the glass goes to the cutting room where it is cut into the desired dimensions, sorted, and boxed ready for shipment.

GREEN GLASS OR BOTTLE GLASS.

Green glass or bottle glass, as it is commonly known, is manufactured from lower grade sands than window glass or plate glass. Sands containing from 5 to 7 per cent of iron oxides have been used. However, the better the grade of sand used the better will be the grade of bottles produced. Color is not the important factor in bottle glass, but these are the requirements of such glass: (1) It must be sufficiently strong to resist the presure of fermented and effervescent liquids. (2) It must be strong enough to resist the shock of ordinary use. (3) It must be sufficiently insoluble to resist the solvent action of corrosive liquids.

The glass manufacturers also place upon bottle glass the requisites: (1) It must be comparatively fusible. (2) It must be easily worked. (3) It must be readily annealed.

The batches for bottle glass are fused in continuous tank furnaces because they are the most economical to manipulate. Bottles are still both hand blown and machine made. For hand blown bottles the gatherer uses a hollow iron rod some 5 or 6 feet in length and

supplied with a slightly enlarged end called the nose upon which the glass is gathered from the ring inside the furnace. Several gatherings may be necessary to secure just the amount of glass required for a given bottle. The mass of glass metal on the end of the blow pipe is distended somewhat and then placed in an iron mold, which has the same interior shape as the exterior of the bottle desired. The blower then blows the glass until it completely fills the mold. The mold is opened and the bottle is broken off the gathering rod or blow pipe at the neck of the bottle.

The neck of the bottle is fashioned by another workman who heats the bottle to the requisite temperature in a glory hole, which is a special small furnace designed for this purpose. After the neck has been perfected the bottle goes to the annealing oven. When the bottles are properly annealed they are sorted, and packed ready for shipment.

Many improvements have been introduced in recent years in the manufacture of bottles, and many bottles are now blown by compressed air. The gatherer gathers with a light rod the amount of glass required for a bottle and places it in a mold which has the shape of the neck of the bottle and a plunger is brought down upon the viscous glass and presses the neck of the bottle into the desired shape. The glass blank is then placed in a second mold which has the shape of the desired bottle, and the bottle is then blown by compressed air into the shape of the mold. The mold is opened and the bottle is transferred to the lehr for annealing. When properly annealed the bottles are sorted, and packed ready for shipment.

It was the privilege of the author to visit, last June, one of the 14 factories of the Owens Bottle Company and study an Owens' automatic gathering and blowing machine in full operation. The machines may be: (1) A single mold. (2) A double mold. (3) A triple mold.

The batch is fused in a continuous tank furnace with a revolving fore hearth. The glass for each bottle is gathered by dipping a preliminary form into the glass mouth down and exhausting the air so that the glass rises in the form and is automatically cut off when the form is full.

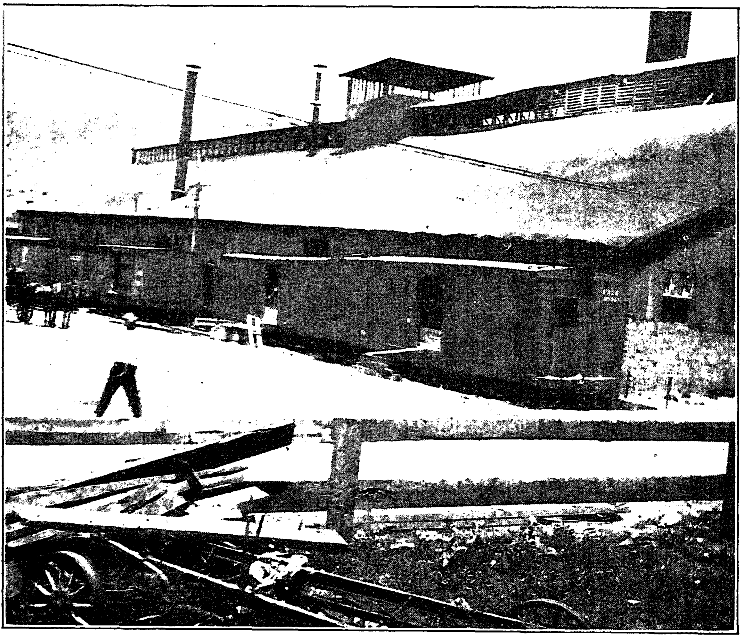
The viscous glass now lowers into a mold which is the exact shape of the bottle desired. The mold automatically closes around the viscous pendant and chills somewhat the exterior of the glass. Compressed air is driven into the center of the cylinder of glass until the bottle assumes the exact shape of the mold. The air takes the line of the least resistance, which is down the center of the cylinder. The bottles are moved mechanically from the mold and placed in the annealing lehr where the finished products are gradually cooled in the continuous kiln for about three hours. The lehr is 70 feet in length and the temperature of the feeding end is 1,000 degrees F.

The material is not touched by man from the mixing and feeding of the batch until the bottles are removed from the cold end of the

lehr for sorting, packing and shipping. No fire glazing is used in finishing the mouth of the bottle, for the bottle is perfect as it comes from the annealing oven.

The most complex machine watched was a triple Owen's automatic gathering and blowing machine which manufactured 1,300 gross of bottles per day, or 56,160,000 per year. Larger Owen's machines have been manufactured, some of which contain as high as 10 molds and turn out 25 bottles per minute.

The Owens factories are located: (1) With reference to a large and practically inexhaustible supply of good glass sand. (2) With reference to a large and ready market for the finished product (3) With reference to a natural gas supply as the ideal fuel. (4) With reference to a large supply of bituminous coal from which producer gas may be manufactured. (5) With reference to a large supply of petroleum, which may be used as fuel.



(4.) Freight train for shipping glass. Thatcher Manufacturing Company, Clarksburg, West Virginia.

FLINT GLASS.

Flint glass includes a myriad of forms other than window glass and plate glass. All true flint glass contains lead, which imparts to it its characteristic brilliancy and weight. It is the choicest ma-

terial for table ware, cut glass ware, optical glass, and the highest grade of blown and pressed ware that adorns the home. Covered glass pot furnaces must be used in fusing the batch.

Formerly all lead flint glass was made by hand, but now both blowing and pressing machines are widely used.

In the process as watched in one factory, a hollow metal rod is inserted into the batch of glass, which is in a state of perfect fusion. The cold metal serves as a bait. Enough glass is gathered for a single tumbler. This is rolled back and forth in the air to give it uniform consistentcy. The material is then worked over a metallic iron slab or marver. The glass is then distended a little by the breath and placed in a mold that elongates the glass. It is then placed in a mold that is the exact form of the tumbler desired. The glass is removed from the gathering rod by touching the neck with a cold metal and adding water to effect the fracture desired. The tumbler is now placed by tongs in a tray kept warm by gas. When the tray is filled the tumblers are placed in a cooling oven, where the cooling is gradual to prevent fracture. After the tumblers are removed from the cooling oven they are marked by a carborundum wheel at the altitude the tumblers are to be cut. Each tumbler is then placed in a metal form where between two metals a narrow gas flame cuts off the top of the tumbler. The rim of the tumbler is then ground on an emery wheel to an even tho sharp surface, and then fire glazed on the rim. The tumblers are now ready for sorting, packing and shipping.

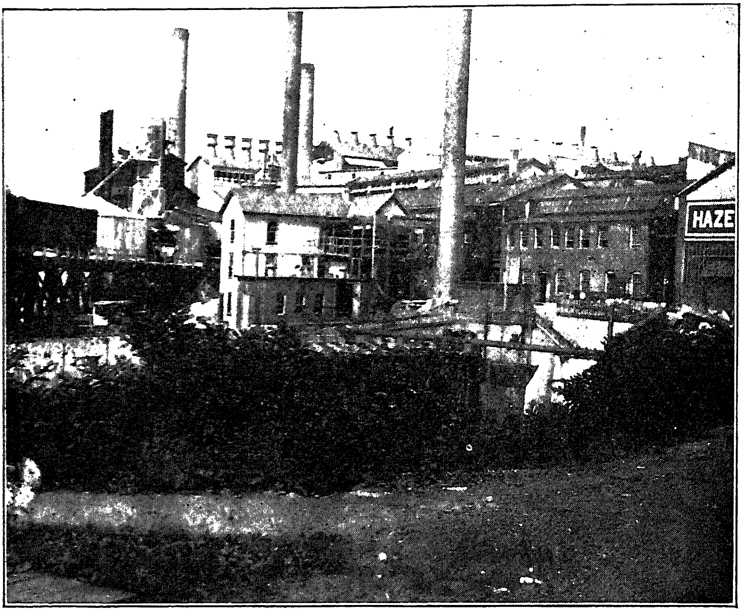
CUT GLASS.

Cut glass is first blown into the form desired from the brilliant water white crystal metal. It is then ground into a cluster of glistening facets. Grindstones continuously moistened with a stream of wet sand cut the rough pattern and finally putty powder is used to finish the brilliant angles.

PRESSED GLASS.

Pressed glass is the least expensive kind of lead flint glass. The pressing machine contains a mold of the object to be made. One workman gathers the molten glass, cuts it off, and drops it into the mold of the pressing machine. Another workman pulls a lever which throws down a plunger and the glass is pressed into the exact form of the mold.

Some practical differences between American and Bohemian cut glass are: (1) In the American product the facets are cast instead of cut. (2) The angles are rounded instead of sharp. (3) The luster is less brilliant.



(5.) Glass Factory of the Hazel-Atlas Glass Company, Clarksburg, W. Va.

OPTICAL GLASS.

Optical glass is the most difficult of all the lead flint glasses to manufacture. It requires the greatest care in the selection of the raw materials, and the greatest skill and patience in the workmanship.

The batch for optical glass can be fused only in covered pots. The glass pot furnace contains only one pot, therefore it is unlike the other glass pot furnaces heretofore described. The pots also have thinner walls than those for the manufacture of ordinary lead flint glasses. When the batch has been thoroughly melted and perfectly fined all the glass gall is carefully removed and the stirring of the glass begins. Stirring is necessary to render the glass perfectly homogeneous and free from striae. The pot is removed from the furnace and allowed to cool rapidly for 30 or 40 minutes. It is then placed in an annealing oven and cooled slowly for 3 or 4 days. The pot is next drawn from its fire clay shell and broken away from the contained glass. The broken fragments of perfect glass are reheated and molded into plates, blocks, or discs, as desired, and placed in a lehr, where they are annealed. The time of perfect annealing requires from 10 to 12 days. When the annealing has been completed the glass forms are termed blanks and are ready to be cut into lenses or other optical ware.

WIRE GLASS.

Wire glass, as its name implies, is a combination of wire and glass which is used in large buildings like gymnasiums and railway stations where a single wide arched roof must span a large area. It is also used for ordinary windows in exposed locations as a precaution against fire or other accident.

The first successful process of manufacture was patented by Frank Shuman in 1892. In this process a large iron table is set on the floor and heated by gas from beneath. The molten glass is poured over the table. A machine holding four rollers and feeding out the red hot wire netting is rolled over the table with a truck. The first roller smooths and spreads out the glass. The second presses into the glass the wire netting. The third and fourth rollers complete the process of smoothing and hardening the wire glass.

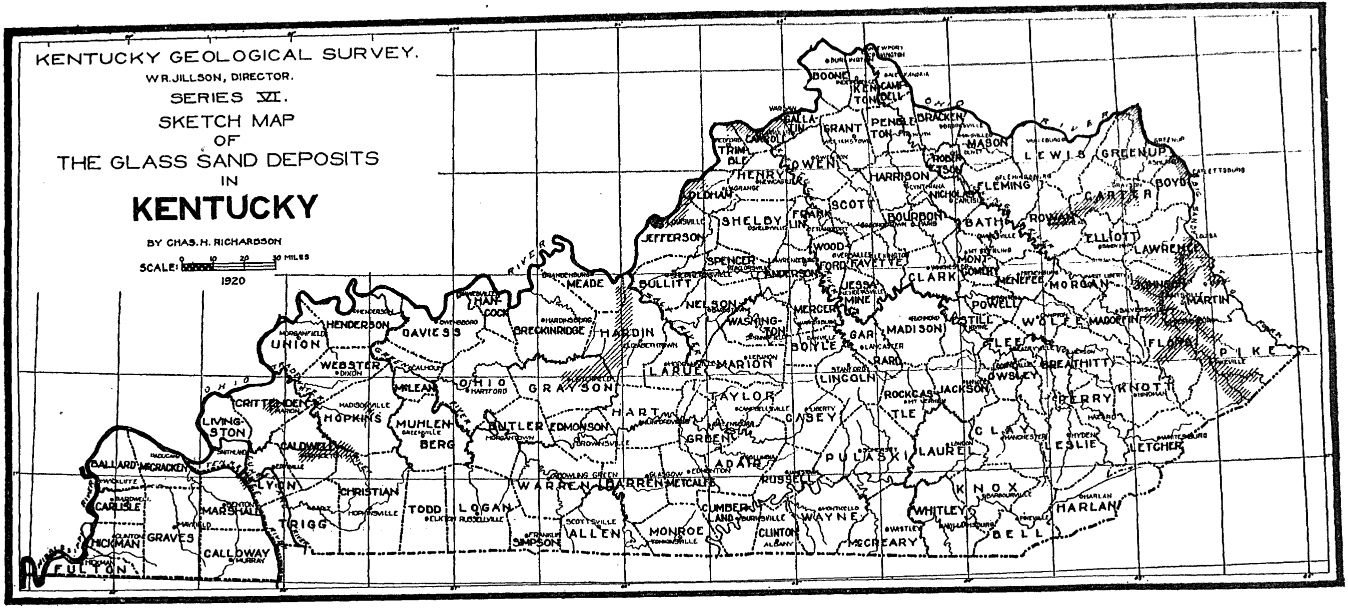
GOBLETS.

In manufacturing a goblet the worbman dips his rod into the molten material and brings out just enough molten glass to make the body and stem of the goblet. He works this by rolling it back and forth on a steel plate or marver to give solidity to the glass and uniformity also. Then he raises the pipe holding the material in the air and blows in it to start the goblet.

It is then passed to a secord workman, who by rolling it on a piece of steel makes the stem of the goblet. Then it passes to a third workman who puts the goblet in a mold of the shape of the goblet desired, and blows thru the hollow iron tube until the mold is filled and the body is completed.

The stem is put on by one man dipping out just enough molten glass to make the bottom, rolling it in the air and holding it over the upturned stem of the goblet. Then a man cuts off the excess of molten glass with a pair of shears. The glass adheres to the stem. He then rolls and works the material until the bottom is complete.

It is then marked with a file by a fifth man and the goblet taken off the blowing rod. It is then taken by a sixth man who places it in a lehr or annealing oven. After removal from this oven the goblet goes to a marker with a carborundum wheel which marks the height of the goblet and with a snap of the wrist the top is thrown off. The goblet then goes to another workman, usually a woman, who grinds the rim of the goblet to a sharp, smooth edge. A woman then feeds the goblet into the automatic fire glazing machine which carries the goblets around gas burners, the goblets turning as the large machine turns. One revolution of the large machine completes the fire glazing. The goblet is picked off by a woman, and when cooled is ready to be sorted and packed.



(6) The glass sands (hachured areas) of Kentucky.

CHAPTER XIII.

GLASS SANDS OF EASTERN KENTUCKY.

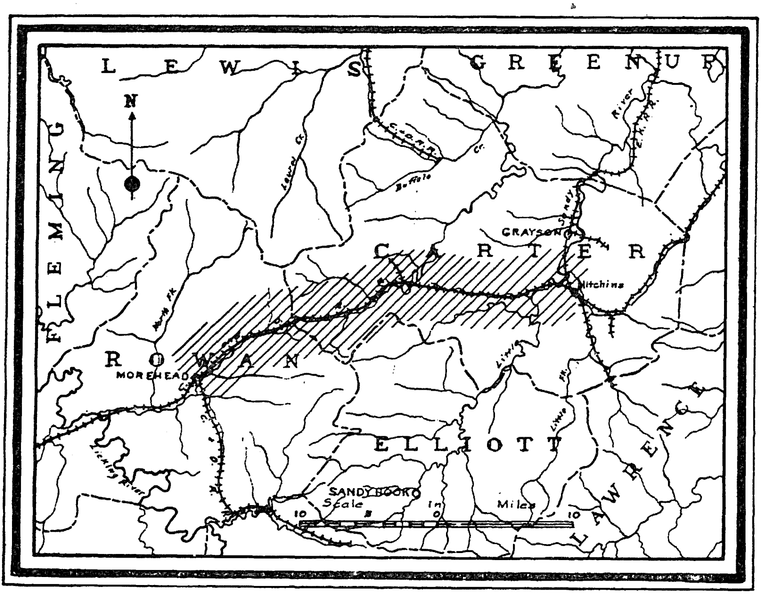
The glass sand deposits of Kentucky may be located in three more or less widely separated fields. (1) The eastern part of the state, which includes the section from Greenup county on the north to Pike county on the south. It also includes Carter and Rowan counties. This entire field will be described as Eastern Kentucky. (2) The northern part of the state, which includes the section extending from Carroll county on the northeast to Grayson county on the southwest This will be described as Northern Kentucky. (3) The western part of the state, which includes Crittenden, Caldwell and Hopkins counties. This field will be described as Western Kentucky. Other isolated localities will be noted, but they do not appear to be of sufficient importance to warrant their being listed as special fields.

For the general distribution of the glass sands of Kentucky (See Ills. 6.)

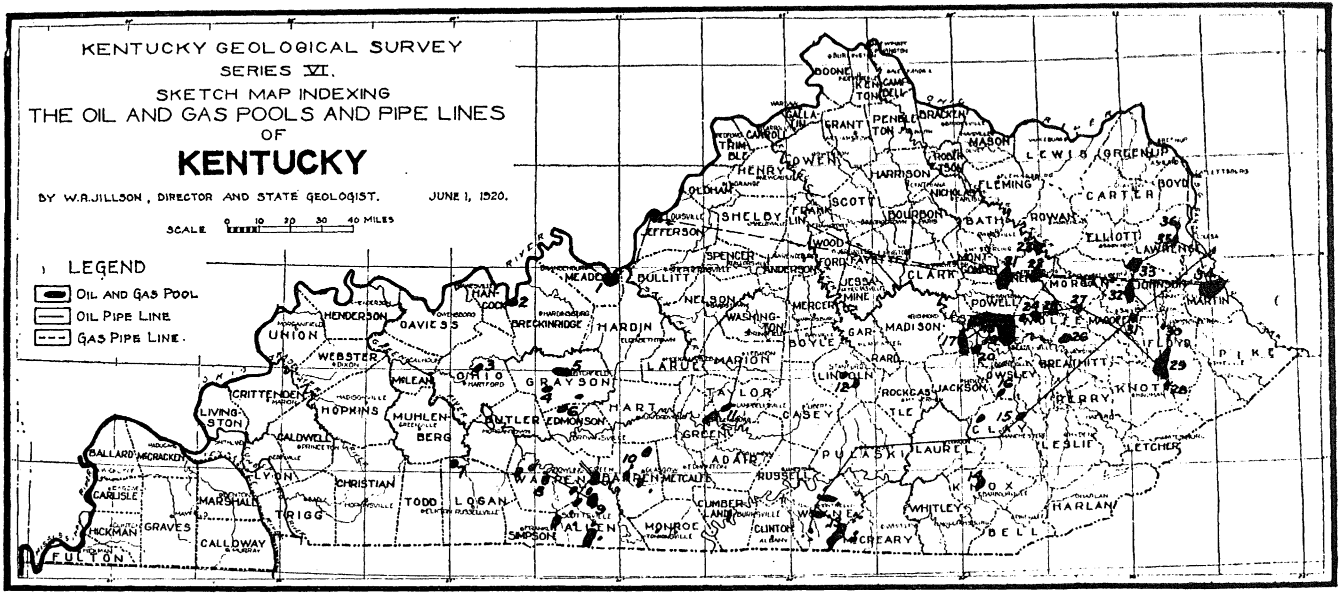
Each of the large fields above referred to will be subdivided into districts, and each district taken up by counties, because of the advantage that this method possesses for future reference.

OLIVE HILL DISTRICT.

The Olive Hill district embraces Carter and Rowan counties in the eastern part of the state. They lie to the southeast of Fleming



(7.) Sectional may showing distribution of Glass sands, Olive Hill District.



Sketch map showing location of oil and gas fields in Kentucky for the development of Kentucky glass sand deposits.

and Lewis counties, and to the northwest of Elliott and Lawrence counties. The area is traversed by the Chesapeake and Ohio railroad.

For the location of the glass sand deposits in this district (See Ills. 7.)

The sandstone of this district owes its value as a glass sand to the fact that comparatively pure quartz sand was laid down on the floor of an ancient sea, compressed and cemented together, and that disintegration has proceeded to a point where the sandstone is soft, friable, and easily reduced to individual sand grains containing little else than pure silca.

CARTER COUNTY.

OLIVE HILL.

All the glass sands of Carter county are Pennsylvanian and Mississipian in age. Some of the best of these are situated above the bluish gray Buena Vista sandstone that is used for building purposes, and is also Mississipian in age. They belong to the Waverly formations.

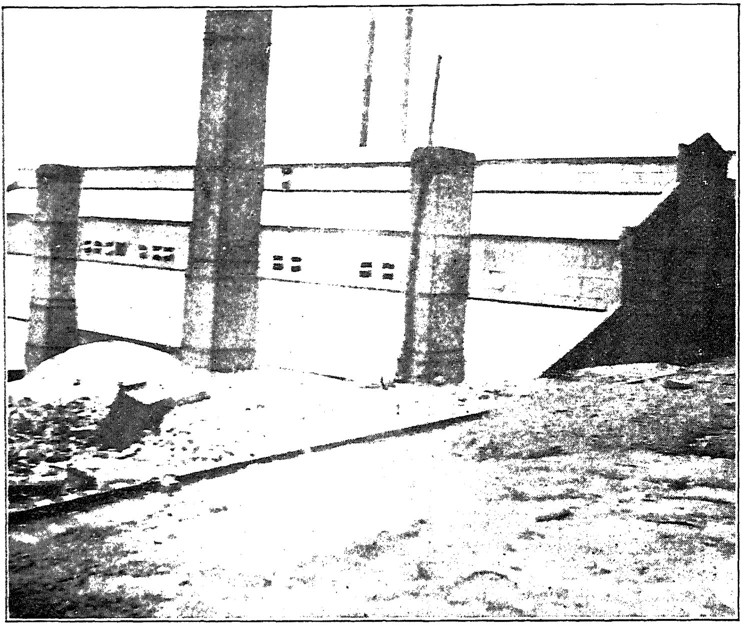
Others occur as at Olive Hill in the basal Pottsville. The glass sands extend somewhat intermittently by erosion from Leon about 10 miles east of Olive Hill westward into Rowan county.

The General Refractories Company, of Olive Hill, operates a quarry of sandstone which is situated about one-half mile west of their factory and just above the Chesapeake and Ohio railroad. The lower 15 feet of this sandstone is white or faintly yellowish white in color, free from grains of feldspar, and practically free from scales of mica. The grains are angular to subangular, and easily loosened from each other when struck with a hammer. In fact the stone is so friable that it can be very easily reduced to a silica sand well suited for the manufacture of glass.

A small crusher is installed at the quarry which crushes the glass sand without washing. A permanent supply of water in the creek a few hundred feet away would make the washing of this glass sand comparatively easy. An analysis of a sample of this sand will appear in the chapter on analyses of glass sands. The upper 20 feet of the quarry is iron stained from the ground water carrying the iron compounds in the overlying soil down among the more loosely cohering sand grains. The iron stained sands of this quarry when washed with the white sands of the lower beds should make a fairly white glass sand, as careful washing will remove much of the iron stain.

The iron stained sand is now used as an excellent molding sand. It is spread over the floor of the factories of the General Refractories Company and the Harbison-Walker Brick Company to keep the green brick from sticking to the floor, and on the inside of the molds in which the brick are pressed to prevent the brick from adhering to the

molds. Incidentally this sand is also used for mortar, plaster, cement and concrete. The price of this sand for local consumption is $2.00 per ton.



(9.) Plant of the General Refractories Company, Olive Hill, Carter County, Kentucky.

Pure white sandstone beds aggregating 20 to 30 feet occur on the opposite side of Tygart Creek, 2 miles southeast of Olive Hill, and up Bens Run on land owned by Thomas Kaiser. In fact, wherever the altitude of the quarry of the General Refractories Company is reached, the white sandstone may be expected to occur.

Sandstone suitable for the manufacture of glass occurs on the farm of G. H. Bolling, 4 miles southwest of Olive Hill, and about one mile from Limestone railway station. The sandstone here forms a bluff on the Flat Fork of Tygart Creek. Some 15 or 20 feet of the sandstone is white or nearly white. A permanent water supply can be obtained from the creek only a few hundred feet from the sandstone cliff for washing the sand. This sandstone is friable and easily crushed to grains of silica sand. The post office address of Mr. G. H. Bolling is Globe, Kentucky.

LAWTON-TYGART.

A little confusion may arise here unless it be kept clearly in mind that the name of the post office is Lawton and the name of the railway

station is Tygart. The Camp Glass Company, of Huntington, W. Va., owns and operates two quarries at Tygart. These quarries are situated on the south side of the Chesapeake and Ohio railroad and only a few hundred feet from the track. A spur extends to the crusher and storage bins. The elevation of the quarry is some 100 feet or more above the track.

(10.) Blocks of sandstone show rift at the plant of the Blue Grass Quarries Company, Bluestone, Carter County, Kentucky.

The sandstone beds vary in thickness from 30 to 40 feet. The upper 15 feet is more or less iron stained thru the leaching of iron oxides from the overburden of soil and their migration downward by circulating ground waters. The lower 15 to 20 feet of sandstone is white or faintly yellowish white in color, of medium grain, angular to subangular in form, and well suited to the manufacture of all kinds of glassware.

The sandstone from the quarries, which are only a few hundred feet apart and continuous if the overburden of the soil was removed, is carried to the crusher in small cars and delivered to the top of the crusher. A Champion vibratory jaw crusher is used in breaking down the sandstone. From the crusher the sand passes to the chaser, where two large wheels, revolving on a horizontal axis, reduce the sandstone lumps to individual grains. The sand goes from the chaser to the washing pans and is carried from the washing pans by screws, ele-

vated 12 feet in 100 feet, from which the sand is discharged into V-shaped troughs and delivered directly to the storage bins for shipment. A dryer was found at the plant but not installed.

Mr. F. F. Riggall, secretary of the Camp Glass Company, writes: "The company located in Huntington, West Virginia, in 1913. They moved their operations from Mt. Vernon, Ohio, owing to the failure in the natural gas supply in that section. Shortly after starting operations in Huntington, they were confronted with a shortage of glass sand, originally figuring on a supply from Tygart Station, Kentucky. In order to give them an ample supply of glass sand the Camp Glass Company took over the glass sand operations owned by W. W. Hillman at Tygart. Since that time the company has had a sufficient supply of sand for their own factory, and have furnished quite a number of factories in West Virginia and Ohio with this high grade glass sand."

The factories in the western part of West Virginia are in readiness to use Lawton-Tygart or Olive Hill glass sands just as soon as crushers and washers are established of sufficient magnitude to warrant a permanent supply of glass sand.

The supply of sand is ample to meet all demands. The freight rate on sand from Berkeley Springs, West Virginia, to some of these factories was given as varying from \$3.50 to \$4.00 per ton. The Olive Hill or Tygart glass sands can be delivered to the same factories with a freight rate less than \$1.00 per ton. The rate was given in one instance as \$0.60 per ton. The price of the sand is \$2.50 per ton F. O. B. Tygart.

This sand is also used as a molding sand, in steel foundries for both molding and holding on heating beds, for building sand and grading sand. The American Car and Foundry Company, of Huntington, West Virginia, secures their sand at Tygart, Kentucky.

As will be seen in the chapter on analyses, this glass sand runs very high in silica and low in iron content. Silica 99.45 to 99.10, and iron oxide from 0.04 to 0.13 per cent. New analyses of samples collected this summer may somewhat change these percentages.

ENTERPRISE.

Dr. G. R. Logan, of Enterprise, owns a most excellent glass sand deposit. This outcrop is 2 miles due west of Lawton and about one-fourth mile from the railroad on the Soldiers Fork of Tygart Creek. The sandstone bed is 30 feet in thickness and at least one-fourth mile in length. This sand appears to be exceptionally good glass sand.

SOLDIER.

Beds of white sandstone some 30 feet in thickness occur 5 miles due north of Soldier on Flemon Hill on the farm owned by Matthew Evans. It is reported that the overburden of soil is thinner here than in the localities already described and that the overlying stained sand beds are also thinner. This outcrop may be catalogued as a glass sand reserve.

ROWAN COUNTY.

Glass sands continue to the west of Soldier, a distance of some 5 miles into Rowan county, and to the east in Carter county to Leon, some 15 to 20 miles distant, which would make the two belts of white glass sand in Carter and Rowan counties some 20 to 25 miles in length. They extend both north and south of the Chesapeake and Ohio railroad from 5 to 10 miles.

(11.) Rowan County white sand grains showing exact size,

J. H. Molby, of Olive Hill, reports the existence of a white sandstone cliff some 22 miles west of Olive Hill and within 2 miles of the railroad. This would bring the outcrop into Rowan county. The cliff is said to be some 75 feet in height, and essentially all glass sand.

FARMERS.

At Farmers the typical white and yellowish white sandstone so well adapted for the manufacture of excellent glass sand has been largely removed by disintegration and erosion. The bluish gray freestone so well developed at Freestone and Farmers is now the exposed formation.

The Rowan County Freestone Company of Farmers, Kentucky, operates a sandstone quarry on the brow of the hill just south of the village of Farmers. A section as taken in this quarry is here given, reading from the quarry floor to the top of the quarry.

1. 14 inches thick.
2. 28 inches thick.
3. 21 inches thick.
4. 30 inches thick.
5. 14 inches thick
6. 18 inches thick.
7. 18 inches thick.
8. 11 inches thick.
9. 12 inches thick.

These beds are all separated from each other by beds of clay or shale varying from 1 to 8 inches in thickness.

All the beds are merchantable. Numbers 5 and 7 are used for rip rap and railroad ballast.

FREESTONE—BLUESTONE.

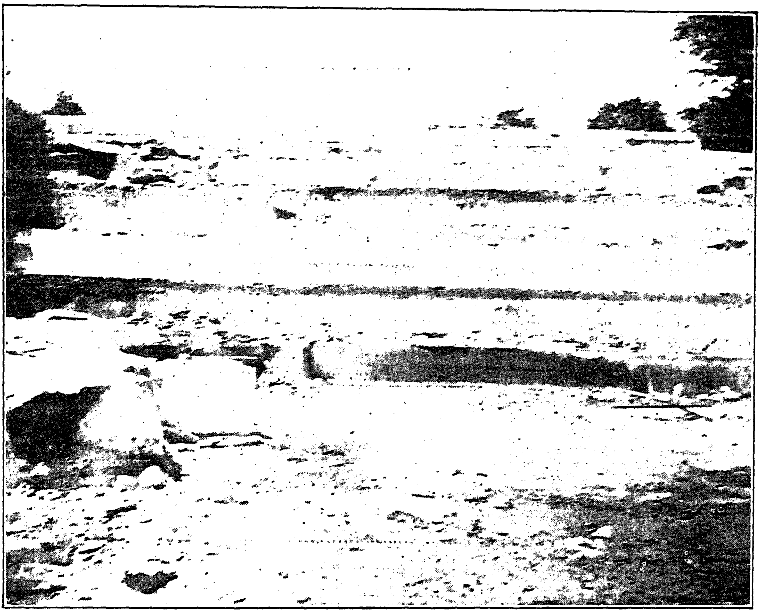
The name of the post office here is Freestone and that of the railroad station Bluestone. The Blue Grass Quarries Company owns and operates a quarry a little south of the Bluestone station. At the quarry there are 13 beds of bluish gray, fine-grained sandstone whose value as a glass sand possibility must be determined by the chemical analysis which will be found in the chapter on analyses. (See Ills. 10.)

The beds are separated from each other by thin beds of clay or shale varying in thickness from 1 to 18 inches. The sandstone beds vary from 4 to 32 inches in thickness. A section measured from the bottom up is here given:

1. 14 inches thick, not quarried.
2. 32 inches thick, bluish gray.
3. 22 inches thick.
4. 30 inches thick.
5. 8 inches thick.

6. 18 inches thick.
7. 18 inches thick, best grade of quarry.
8. 10 inches thick.
9. 6 inches thick, steel gray.
10. 15 inches thick, buff colored.
11. 11 inches thick.
12. 12 inches thick.
13. 5 inches thick.

All the beds are merchantable, save numbers 5 and 13. The thinner seams are used for flagging. All the beds lie practically in a horizontal position. (See Ills. 12.)



(12.) Sandstone quarry of the Blue Grass Quarries Company, Bluestone, Carter County, Kentucky.

From an old analysis made by Dr. Robert Peter the silica content of this sandstone is given as 93.128 per cent. The compressive strength is 15,724 lbs. per square inch, and the transverse strength 4,152 lbs., as determined by the Watertown Arsenal, Watertown, Mass.

LOGS.

Thru the courtesy of Ralph E. Hitchins, of the General Refractories Company, the author has been given several sand logs that will be of interest.

1. Olive Hill District.

Surface	10 feet	inches
Shale	10 -52	
Aluminous clay	52 -52.8	
Sand	52.8-82	
Ocher	82 -89.6	
Limestone	89.6-90	

At which depth drilling stopped.

2. Olive Hill District.

Surface	12 feet	inches
Shale	12 -66	
Sand	66 -92	
Ocher	92 -99	
Limestone	99 -100	

At which depth drilling stopped.

3. Olive Hill District.

Surface	10 feet	inches
Shale	10 -60	
Sand	60 -90	
Ocher	90 -94.6	
Limestone	94.6-95	

At which depth drilling stopped.

4. Aden District.

This district is located 7 miles east of Olive Hill.

Surface	0 feet	inches
Sand	88.6	
Coal	1.6	
Flint Clay	1.6	
Soft clay	5.6	
Red ocher	4.	

5. Lawton District.

Surface	11 feet
Shale	11 -14
Harder shale	14 -26
Sand	26 -40

6. Lawton District.

Surface	6 feet
Shale	6 -38
Sand	38 -94
Ocher	94 -98
Sand	98 -102

7. Soldier District.

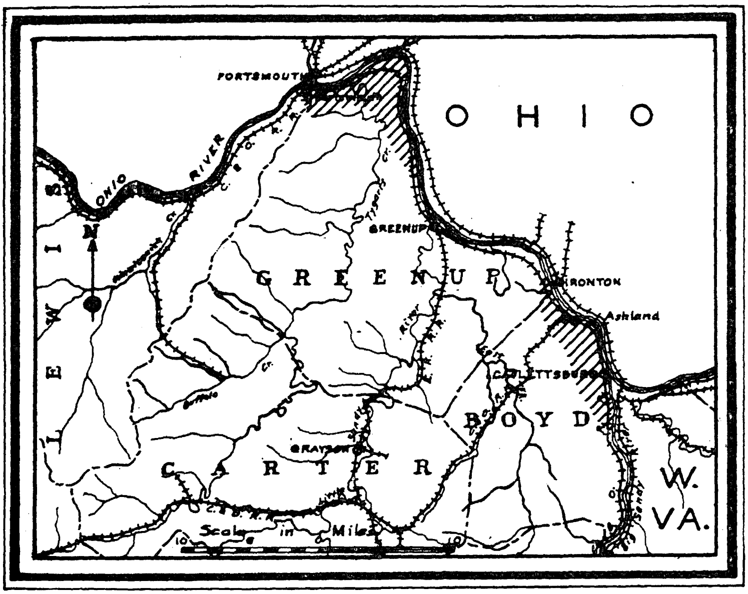
Sand	16 feet	inches
Shale	16 -34	
Clay	34 -37.6	
Red ocher	37.6 -60	

8. Soldier District.

Sand	27 feet
Shale	27 -56

ASHLAND-CATLETTSBURG DISTRICT.

This district comprises Boyd county, which borders the Ohio river on the east. It lies south of Greenup county and north of Lawrence county. (See Ills. 13.)



(13.) Sectional map showing distribution of Glass Sands in Ashland-Catlettsburg District, and the South Portsmouth District.

ASHLAND.

The Ohio river sands are, strictly speaking, building sands in the neighborhood of Ashland, and are utilized as such. However, by washing and screening, glass sands of uniform grade can be secured. The Ashland Glass Company, as previously noted, is located at Ashland. It is not a factory which manufactures glass, but one which does most excellent work in cutting and decorating glass.

The massive sandstones near Cliffside Bluffs, just south of Ashland, were carefully examined, but the sandstones appear to be too massive and too dark colored for use as glass sands.

CATLETTSBURG.

In the bluffs in the fourth ward of Catlettsburg there is a fairly white sandstone bluff some 25 or 30 feet in height. This bluff is further located at Pike's crossing on land owned by Charles Billips. Where the winds have removed impurities that may have been brought down by circulating waters the sandstone is fairly white in color. This sandstone sometimes attains a thickness of 73 feet. It is the Mahoning Sandstone, which is of Pennsylvanian age.

The percentage of silica of this sandstone appears in the chapter on analyses in this report.

Just south of Catlettsburg in the valley of the Big Sandy, there is a large area covered with glass sand, building sand, etc., and overlain with a mantle of sandy soil. This sand is best seen at the river bank during low water.

SANDY CITY.

Sandy City is situated between Ashland and Catlettsburg on the Ohio river. It is some 2 miles north of Catlettsburg and 3 miles south of Ashland. The street car stop is Broadway. The best river sands in this section are located on land owned by B. H. Harris, State Senator from this district.

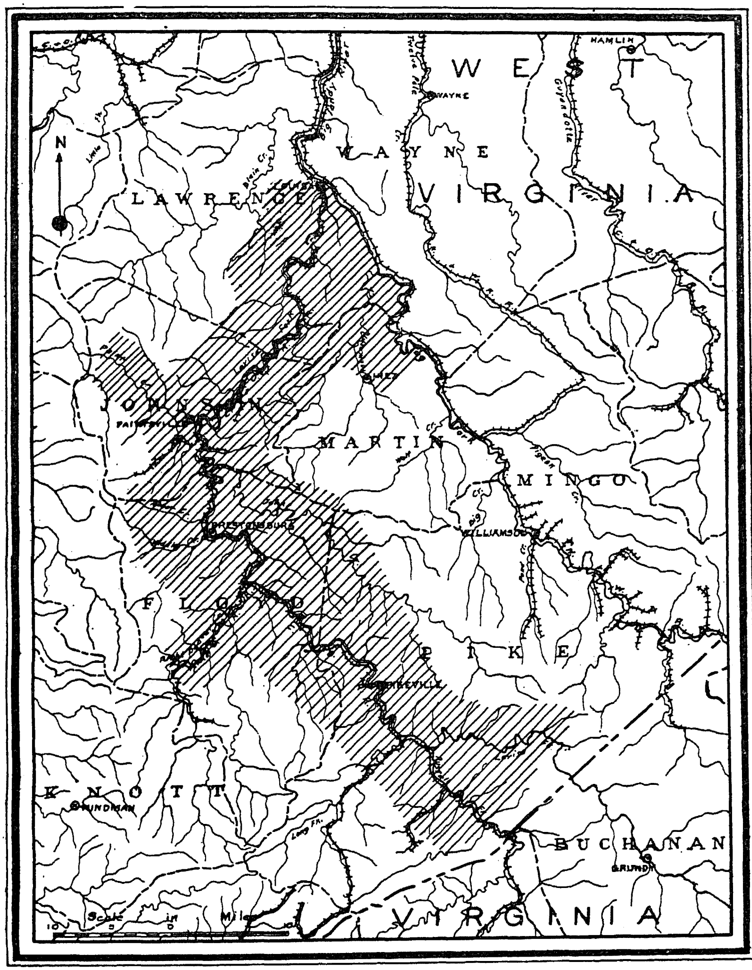
The river sands extend some 2 miles or more along the western shore and in the bed of the Ohio river. By reported well diggings the merchantable sand extends westward from the river some 1,200 feet and is here covered with a mantle of sand mixed with clayey matter and river wash. This sand is sharp, angular to subangular, and may be washed and screened to a glass sand of uniform size. The coarser screenings can be used as building sand, while the coarsest material can be used with gravel in the manufacture of concrete.

The sand contains some scales of mica which would be largely removed in the process of washing. It also contains some grains of coal which would in part be screened out, while the remaining coal would be consumed in the fusion of the glass batch. It is interesting to note that a glass company once operating at Covington, Kentucky, is reported to have used this sand for the manufacture of glass until it removed to Indiana, where natural gas was available as fuel. The author could not ascertain that this company was in any way dissatisfied with the glass sand.

The sand bed has one decided advantage. As fast as the sands are pumped out and washed the pit would be filled again by the great burden of sand in the bed of the Ohio river.

BIG SANDY DISTRICT.

The Big Sandy district includes what is generally spoken of as the Big Sandy valley. It embraces Lawrence, Martin, Floyd and Pike counties in the extreme eastern and southeastern part of the state. For further location (See Ills. 14.)



(14.) Sectional map showing general distribution of Glass Sands in the Big Sandy Valley.

LAWRENCE COUNTY.

LOUISA.

At the point where the Tug river and the Levisa Fork of the Big Sandy meet to form the Big Sandy river at Louisa, there is between the two branches a V-shaped area of considerable dimensions of possible glass sand. These sands are medium in size, angular to subangular in form, and fairly white in color. They contain some scales of mica which would be removed largely by washing. Also a few dark colored quartz grains, a few feldspar grains, and some coal grains. This sand is a good building sand, and has been used for that purpose.

ZELDA.

According to Col. J. H. Northrup, of Louisa, the Covington Glass Company, when manufacturing glass at Covington, Kentucky, worked the Ohio river sands at Zelda for several years. When they removed their plant from Covington, Kentucky, to Muncie, Indiana, on account of the supply of natural gas near Muncie, they ceased to work the large sand deposits at Zelda.

BUSSEYVILLE.

According to H. V. Tygrett, of Bowling Green, field assistant on the Kentucky Geological Survey, a sandstone cliff some 50 feet in height occurs at Busseyville, about 7 miles south of Louisa and about 3 miles west of Torchlight. The sample submitted of this sandstone, which is now being quarried for building purposes, is nearly white in color, medium grain in texture, and contains a few scales of muscovite. It is the Homewood sandstone, of the Pottsville formation, and is best catalogued as a glass sand reserve.

MARTIN COUNTY.

It was reported by civil engineers using in construction work the sands from Tug river that they proved perfectly satisfactory in every way for plaster, mortar, cement, and when mixed with gravel, concrete manufacture. With the number of coal mines located along the Tug river these sands are more heavily charged with coal grains than many other sands of the Big Sandy district.

JOHNSON COUNTY.

PAINTSVILLE.

At the mouth of Paint Creek there is a large amount of glass sand. It is somewhat contaminated with coal and stained yellowish white with iron oxides. Some of this sand was carefully washed in the Levisa Fork of the Big Sandy river, and when dried it was nearly pure white in color. There are some pebbles in the sand, but these would be easily removed by screening. Likewise most of the scales of mica would be carried away in the process of washing.

This sand deposit is said to be from 20 to 30 feet deep. It extends out into the Levisa Fork for several rods at the junction of the two streams and up Paint Creek for more than a mile, so there is an ample supply of sand to refill the pocket with the first high water. This sand is now being used for mortar, plaster, cement and concrete.

Across the John C. C. Mayo swinging bridge over Paint Creek and about 100 rods above the bridge and on the right hand side of Paint Creek, there is a good grained, hard, compact, drab colored sandstone. This sandstone furnished the stone for the Methodist church at Paintsville and the foundation and columns of the John C. C. Mayo house in Paintsville. The large columns are sectional. The small ones are one solid cylinder of sandstone. They show in a marked degree the value of this stone for structural work. These structures were erected about 1905, and show few defects from weathering. The stone pulverizes to a slightly greyish white sand, but its value for glass sand can best be determined by the chemical analysis given in the chapter on analyses.

MAGOFFIN COUNTY.

Near Wheelersburg there is a soft, white sandstone that is easily crushed between the fingers. The grains are loosely cemented with soft clay. There are a few very black specks and scales of mica in the sandstone. The iron content is low, .18 per cent, for an unwashed sand. This sandstone would make a fair quality of glass sand.

FLOYD COUNTY.

PRESTONSBURG.

On Middle Creek, at Prestonsburg, excellent glass sands occur of unknown depth, filling the inner curve of a meander. The sand carries practically no coal grains. It has a few scales of muscovite but not enough of them to interfere in the manufacture of glass. Most of the mica scales would be removed in the washing of the sand.

This sand occurs in several deposits up Middle Creek. Back a little ways from the nose of the meander there is a foot or more of loam that would need to be removed before the deep sand deposits were washed. In making a vertical section in the bank a loam seam 2 inches thick was found, about 2 feet below the surface, but no loam was found beneath this seam. By people who have secured sand here the deposit is regarded as 15 feet in thickness of merchantable sand.

On the Levisa fork at Prestonsburg, where sand is now being hauled for brick, mortar, plaster, cement and concrete, a large tonnage of sand occurs. Piles have been driven into the sand from 20 to 25 feet without striking rock bottom. This sand is also a glass sand. It carries a little more coal than the sands of Middle Creek.

Abbott Creek enters into the Levisa about one mile below Prestonsburg. The sand beds here are not large.

Two miles above Prestonsburg and on the east side of the Levisa Fork there is a sandstone quarry now being opened up for building material. A part of this sandstone is almost a pure white and a part is stained somewhat with iron oxdes a yellowish white color. The cliffs of this sandstone are some 25 to 30 feet in thickness, and 100 feet or more above the Levisa Fork. There are a few scales of mica in this sandstone, but the stone is friable, and when crushed the sand is almost a pure white. It is regarded as a good glass sand. (See Ills. 15.)

(15.) Quarry glass sand, Prestonsburg, Floyd County, Kentucky.

AUXIER.

Johns Creek empties into the Levisa Fork 7 miles below Prestonsburg and about one-half mile below the Auxier railroad station. The large sand bar at the mouth of the creek is a good glass sand. It is nearly white when dry, and it contains a few coal grains that would be largely removed in washing and screening the sand.

Above Auxier for at least one-half mile along the inner curve of the meander there is a large amount of good glass sand. The mantle of river soil near the river bank is very shallow, but it thickens towards the hills to the west. About one mile above Auxier there is

a cliff of about 25 feet of sandstone along the Chesapeake & Ohio Railroad. This sandstone is sufficiently pure for bottle glass and window glass.

Beneath this sandstone there occurs in descending order:

(1) 10 feet of shale.

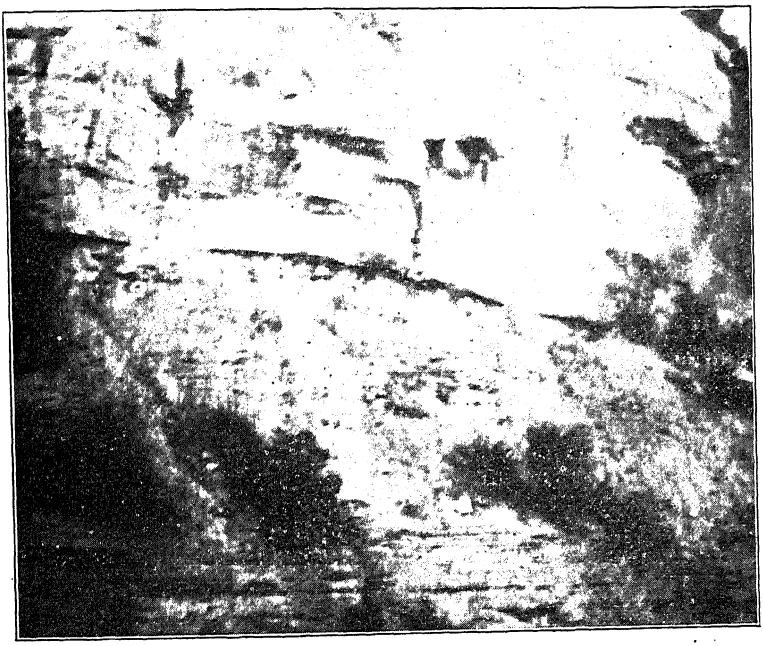
(2) 18 inches of coal.

(3) A thin bed of shale.

(4) A bed of fine grained, drab colored sandstone of unknown thickness, which appears to carry too much alumina for glass sand.

CLIFF.

At Cliff, some two miles below Prestonsburg on the Chesapeake & Ohio Railroad, there is a cliff about 60 feet in height. The upper 30 to 40 feet is a very good sandstone for the manufacture of glass sand. Certain layers are fairly white, while others are somewhat iron stained from the iron content of the soil overburden. The cliff is on the west side of the C. & O. R. R. tracks and on the west side of the Levisa River. (See Ills. 16.)



(16.) Glass sand beds in contact with shale. Glass sand above and shale beneath. Cliff, Floyd County, Kentucky.

A sample was collected from the very bottom of the bed in contact with the underlying shale to see if the lowest portion of the bed as well as the upper portion of the formation was suitable for

glass sand. The fact that this outcrop is situated beside the C. & O. track and not 200 feet from the Levisa River makes the situation very favorable for the crushing, washing, and shipping of the glass sand to various factories.

BEAVER.

Beaver Creek enters into the Levisa Fork of the Big Sandy River some 9 to 10 miles above Prestonsburg. There is a considerable tonnage of glass sand just above the bridge over the creek. This sand was proven over 10 feet in thickness, and its actual depth is unknown. It stretches from the bridge up the creek for about one-half mile. Smaller deposits are located further up the creek.

In some sections this sand is contaminated with a reddish clay, but between the first meander and the bridge the clay is absent, save at the top. At the outlet of the creek there is a larger and equally good deposit of glass sand. A few hundred yards below the outlet and on the opposite side of the Levisa Fork there is quite a large white sand bar. All of these sands are contaminated somewhat with coal grains, which would burn out in the batch. A part of them would be removed by washing and screening. Just above Beaver station there are beds of a sandstone, drab in color and micaceous in composition, that might make a glass sand possibility.

BANNER.

The bluff just below Banner contains a drab colored, good textured, micaceous sandstone that has been quarried for a retaining wall for a siding to a coal tipple. The stone weathers well, works easily, and some 5,000 cubic feet of the stone has been quarried. Its value for glass sand is best determined by the chemical analysis to be found in the chapter on analyses.

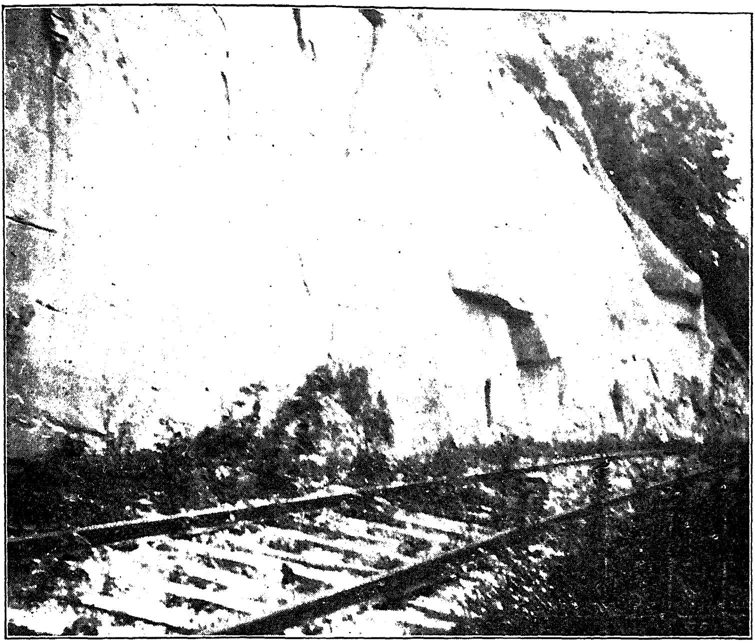
(See Ills. 17.)

PIKE COUNTY.

PIKEVILLE.

The sand bars along the Levisa Fork below the bridge over the river are now being worked for brick, mortar, plaster, cement and concrete. The deposits are at least 15 feet in thickness, and reach nearly to the top of the flood plain. A little overburden of soil could be removed and sands suitable for the manufacture of glass easily obtained.

Above the bridge on the right hand side of the Levisa River and within one-half mile of the bridge, there are three more good sand bars. Within a distance of one mile there are six of these sand bars on the Levisa River. These sands are all coarser than those already described from the Big Sandy District. On the east side of the Levisa and about 20 rods above the bridge there is a fine gravel deposit that is now being extensively worked for the manufacture of concrete. It is an excellent sand for constructional work.



(17.) Massive sandstone, Banner, Floyd County, Kentucky.

On the east side of the Levisa at Pikeville there is a good sandstone for building purposes. It has been used in large quantities in paving the streets of Pikeville. The sandstone works easily and is somewhat micaceous. It is possible that the mica content is too high for a good sand, but the stone pulverizes to a faintly grayish white quartz sand. It is somewhat coarser than the sandstone at Banner. The cliff is 15 feet in height and underlaid by shale. Fifty-four hundred (5,400) cubic feet of this stone has been quarried for constructional and road work.

SHELBY.

At Shelby where Shelby Creek empties into the Levisa Fork there are deposits of excellent building sand. The tonnage is smaller than that at Pikeville, but the sands are similar.

W. T. Mellon, engineer in railroad construction, says that in many of these river deposits of glass sand in the Big Sandy Valley piles have been driven down in bridge work to a depth varying from 15 to 30 feet without striking the bottom of the sand, thereby proving the enormous tonnage of sand in the Big Sandy Valley.

ELKHORN CITY.

According to Charles Butts, geologist of the Kentucky Geological Survey and the U. S. Geological Survey, beds of white sandstone well suited for the manufacture of glass occur in a narrow belt stretching along the Pine Mountain fault in a southwesterly direction from Elkhorn City towards Jenkins. For lack of time in the field, this area was not visited by the author of this report.

SOUTH PORTSMOUTH DISTRICT.

GREENUP COUNTY.

River sands and gravel occur in the bed of the Ohio River between South Portsmouth and Greenup. They are typically angular or sharp building sands.

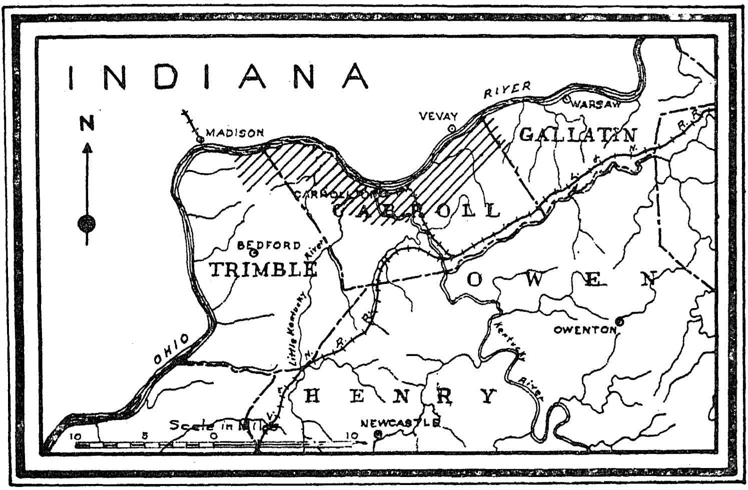
RACCOON FURNACE.

At Raccoon Furnace there is an extensive outcrop of a fine grained friable sandstone of a light-buff color. This stone is composed of rounded grains of sand, a few scales of mica, a little iron oxide stain, and little or no cementing material. The silica is 97.30 per cent, and the iron oxide and alumina content combined is only 0.53 per cent. As this sandstone is nearly pure quartz, and contains so small an iron content, it is well adapted to the manufacture of glass.

CHAPTER XIV.

GLASS SANDS OF NORTHERN KENTUCKY.

The glass sand deposits of northern Kentucky embrace a section extending from Carrollton in Carroll County in a southwesterly direction to Leitchfield in Grayson County. Perhaps Grayson County should not be included here, as the glass sands are continuously from Tip Top in Hardin County to Leitchfield in Grayson County, it seems advisable to include Grayson County in northern Kentucky. (See Ills. 18.)



(18.) Sectional Map showing the distribution of Glass sands in the Carrollton District.

CARROLLTON DISTRICT.

CARROLL COUNTY.

CARROLLTON.

On account of the whiteness of the sand and gravel deposits in Carroll and Gallatin Counties they are locally known as white sand and gravel. These deposits are mostly in Carroll County, but they are reported to extend in a northeasterly direction as far as Dam 39, which is about one mile east of the Carroll and Gallatin County lines. This dam is about 12 miles northeast of Carrollton.

This sand when washed and screened in a 40 mesh sieve is very white and clean. It is sharp, angular to subangular in form. It consists of nearly pure silica or quartz grains. It contains a few small pebbles of jasper and chert, also a few grains of coal. The jasper and chert pebbles are pure silica, and the coal will burn out

in the batch. The length of these white sand deposits is estimated by James Gayle to be 15 miles.

The Grobmyer Coal Company of Carrollton is now mining sand from the northeast side of the mouth of the Kentucky River, but actually in the Ohio River. This sand bar is definitely known to be 25 feet in thickness and of considerable length. The sand is a little coarser towards the bottom of the bar. Quicksand occurs in local beds.

The sand is mined by a clam shell steam shovel and placed on barges, towed by tug boat about 100 rods to a landing. The sand is unloaded from the barge to a hopper, then to a car, screened, and loaded into railroad cars for shipment. This sand is used for plaster, mortar, cement and concrete. It is also a good molding sand. Some 700 tons of sand have already been removed from this bar, but work was begun about July 20, 1920.

Below the mouth of the Kentucky River the sands average a little finer than above the mouth of the river. John Jeter of the Jet Coal & Transportation Company has been mining and removing sand from the Ohio River for 16 years. The Kentucky and Ohio Transportation Company, of which G. W. Geier is the secretary, has mined the Ohio River sands for some 20 years. The sand bar of this company is just opposite the court house at Carrollton. The sand is pumped from the river bottom into deck barges and towed along the Ohio River to various markets. A part is sold to firms in Madison, Indiana, a part goes to Louisville, Kentucky, and a part is locally distributed. This sand when screened to a 60 mesh is nearly pure white in color, sharp, angular sand, and would make an excellent glass sand when properly washed and screened.

During the present year it is estimated that the number of cubic yards of sand removed will equal 20,000. This sand is used as a building sand, in road construction, and as a car wheel sand to prevent the wheels from slipping on the tacks. Craig's sand bar is situated about 7 miles above Carrollton on the Ohio River. It covers same 20 acres or more of good sand, with depth unknown. In some places the adjustment between the sand and gravel is such that it furnishes a product ready for the manufacture of concrete.

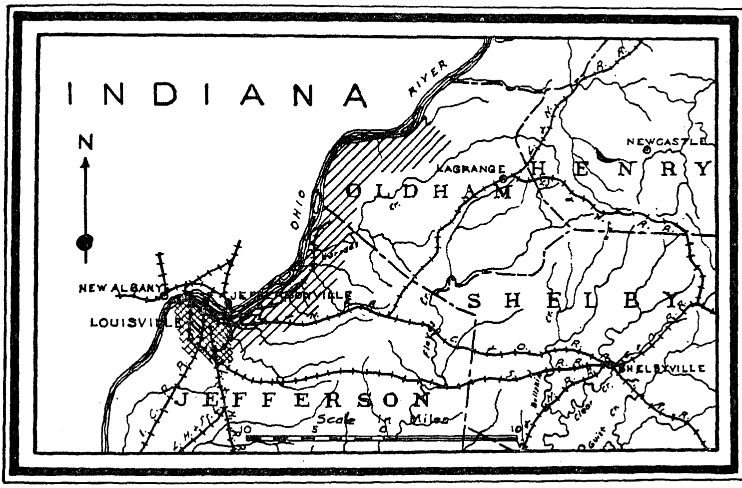
At Dam 39 which is located some 12 miles above Carrollton on the Ohio River the United States Government used the Ohio River sand in the construction of this dam. A normal condition in the white sand and gravel beds here is 40 per cent sand and 60 per cent gravel. The depth of the sand has been measured to 100 feet with practically no change in its mineral content. The sand and gravel bed of the Carrollton Brick Company is an old delta deposit at the confluence of the Kentucky and Ohio Rivers. The pit is only a few hundred feet from the railroad, and the water of the Kentucky River could be used in washing the clayey matter from the sand. Screening properly would remove the sand from the gravel.

LOUISVILLE DISTRICT.

JEFFERSON COUNTY.

LOUISVILLE.

The sand deposits of the Ohio River in Jefferson county extend from Louisville in a northeasterly direction for some 10 miles or more. (See Ills. 19.) Captain Hamilton Duffy, President of the Ohio River Sand Company, has been mining and bringing this sand to Louisville for many years. It is used in the manufactue of plaster, mortar, cement, and concrete. It is yellowish white in color, sharp and angular in form, slightly contaminated with small scales of mica, and in every respect an excellent building sand. This sand when passed thru a 60 mesh sieve is nearly pure white crystalline quartz, and when washed, dried, and screened, would be a good glass sand.



(19.) Sectional map showing general distribution of Glass Sands in the Louisville District.

The supply of this sand between Louisville and the Oldham County line is very large. Like all the other Ohio River sand deposits the pit formed by dredging, or pumping, or scooping out the sand from the river bottom is rapidly filled with a new supply of sand. While there are no glass factories in Louisville manufacturing glass, yet there are three companies that cut and bevel plate glass, and silver mirrors.

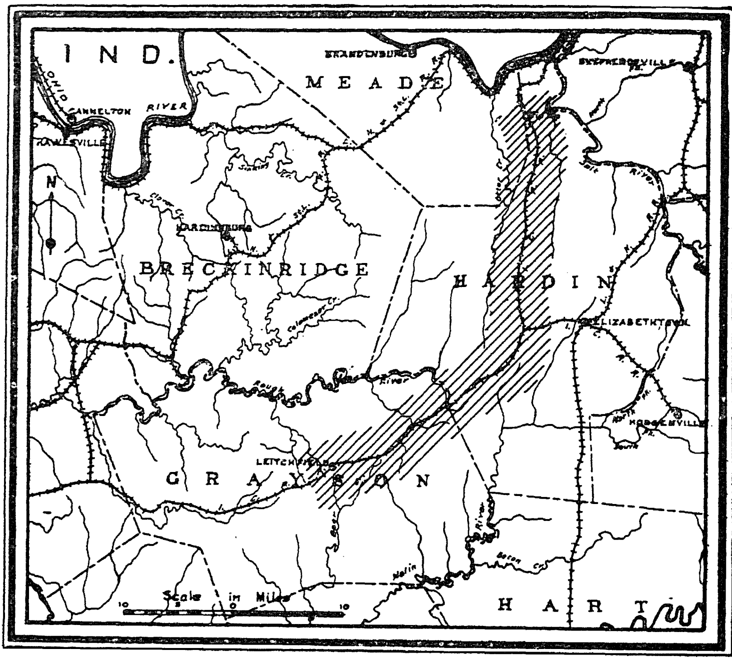
Ohio River sand deposits were reported along the Ohio River extending in a northeasterly and southwesterly direction from Louisville for a considerable distance, but these deposits, for lack of

time in the field, could not be visited by the author of this report. The sands undoubtedly are like the Ohio River sands already described.

LEITCHFIELD-TIP TOP DISTRICT.

This district comprises an almost continuous belt of glass sand extending in a northeasterly and southwesterly direction from Tip Top in Hardin County to Leitchfield in Grayson County. The section is bounded on the northwest by Breckinridge and Meade Counties, and on the southwest by Larue and Hart Counties.

For further location of the district (See Ills. 20).



(20.) Sectional map showing general distribution of Glass Sands in Leitchfield—Tip Top District.

HARDIN COUNTY.

TIP TOP.

The Kentucky Silica Company, with office at 14th and Gallagher streets, Louisville, Kentucky, owns and operates a glass sand pit at Tip Top, Kentucky. F. C. Dickson is president of the company, and Charles A. Williams is secretary and treasurer. The company mines and ships pure silica sand.

The plant of this company is located about one-half mile northwest of the Tip Top station on the Illinois Central railroad, about

one mile south of Muldraugh on the same railroad, and some 28 miles south of Louisville. It is furthermore situated some seven miles east of the Ohio River. These sands are some 400 feet above the mean level of the Ohio River, and glass sand is obtained from the highest points of the upland surface.

According to E. F. Burchard these deposits are Post Carboniferous and probably Tertiary in age and are to be correlated with the Ohio River formations of the Indiana geologists. If the area at Tip Top alone was taken into consideration, this conclusion might easily be drawn. When these sands are found upon field investigation to extend in a southwesterly direction even beyond Leitchfield the field relations argue differently. They probably belong to the Big Clifty formation of Mississippian age.

The sands on the property of the Kentucky Silica Company cover 40 or more acres and are 50 feet in thickness. The deposit consists of a massive sandstone so soft and so poorly cemented together that it crumbles to sand when touched. In color it ranges from white thru yellowish white to yellow. The upper portion for about 25 feet has been stained by iron oxides leached out of the six feet of overburden of soil. The lower beds, some 25 feet in thickness, are pure white save where surface waters have come into contact with them. The grains are very fine, clear quartz sand. In a few instances there are small lenses from two to six inches in thickness of a yellow and white clay interstratified with the sand. The extreme lower portion of the bed carries some small lenses of magnesite. Chert pebbles appear upon the floor of the pit.

The method of mining and washing this sand has been described in an earlier chapter, and need not be repeated here. The sand is classified as follows:

No. 1. Yellow sand, which is sold to founderies as a molding sand, to brick factories to cover the floor to keep the green brick from sticking, and to line the inside of the molds in which the brick are pressed.

No. 1. Glass sand. This sand is a pure white or faintly white glass sand, and is shipped to glass manufacturers as such.

No. 2. Glass sand. This sand is faintly yellowish white and is shipped to the glass factories the same as No. 1 Glass sand.

No. 3. Run of Mine. At the present time the company is shipping a large amount of sand that is called the "Run of Mine" sand. It includes the white beds at the bottom, the overlying iron stained beds, and about 2 feet of the overburden of soil.

No. 4. Heavy Molding Sand. The heavy molding sand is shipped to steel mills for heavy castings. The Louisville & Nashville Railroad is a large purchaser.

These sands are so soft that 80 to 100 pounds pressure of water breaks them up into individual sand grains. When properly washed and screened they find use in plaster, mortar, cement, concrete, molding, casting, fire sand, enamel, glass sand fertilizers. The

white and yellowish white sands may be worked up together and when washed and screened would make a light colored clear quartz sand suitable for good grades of glass.

The white sand when prepared by itself makes a very high grade of glass sand well suited for the manufacture of the best grades of glass produced in America. It is the deep red and somewhat clayey top sand that makes excellent molding material. The source of water for washing the sand is an artificial pond one-third of a mile east of the pit. The water is conducted in an ordinary pipe line to the plant. The water once used is conducted into a settling tank, and the overflow is delivered into a storage tank, so that the water may be used over and over again. The pipe line for washing has five inches suction with four inches discharge. The supply from the pond has 2.5 inches suction and two inches discharge. It would therefore require a run of 16 hours from the pond to supply the plant eight hours.

There is, however, a fine spring of never failing water only a few hundred feet on the opposite side of the railroad. This spring can add materially by storage to the supply of water for washing the sand. A siding only 500 feet in length delivers the cars to the storage bins. Conditions are practically ideal for the production of large quantities of glass sand at this plant.

Sand has been mined at Tip Top on both the east and west side of the Illinois Central Railroad, and on both the east and west side of the state highway. On the west side of the highway the new opening contains an oil charged sand lens varying from four to six inches in thickness. These glass sands were proven to extend beyond the property of the Kentucky Silica Company toward Muldraugh. Also toward the Ohio River on the Dickson farm.

An old pit from which some 20 carloads of sand have been shipped was found on the farm owned by W. F. Scheible one-half mile from Tip Top. The sand was identical with that produced at Tip Top. The sand also appears 1.5 miles southwest of Tip Top on what is known as the Camp Knox Government Reservation, which is an artillery firing center.

EAST VIEW.

The sand pits now operated at East View are owned by E. F. Schwindler of Louisville, Kentucky. The glass sand at this pit has an overburden of soil of three or four feet in depth. The soil grows shallower toward the west. There is about from one to two feet of red to yellowish sand just beneath the soil. This sand is colored largely by the iron content of the soil infiltrating thru the sand. There is from 40 to 45 feet of pure white to a very faintly yellowish white sand. When dry the sand seems perfectly white. The quarry face runs north and south with 200 feet linear dimension. It is situated on the west side of the Illinois Central Railroad and so close to the railroad that the cars are loaded on a passing track.

This deposit covers some 25 to 30 acres on the west side of the railroad with as much acreage on the east side, and of the same grade of sand.

A spur could easily be installed for aid in loading cars, for there is a three-fourths mile of straight railway at East View. There is plenty of water on the property for washing the sand. There are three wells within 100 yards of the quarry, and a large spring some 200 yards away that is not affected by drought. The sand is shipped for foundry sand to the Louisville Fire Brick Company, and for the manufacture of glass it has been shipped to the N. D. Dupaw Glass Company, New Albany, Indiana, and also to various glass factories in West Virginia. The sand contains no lenses of magnesite, no flint nodules, but it does carry a few grains and nodules of pyrite, FeS_2. These can be removed by proper screening.

This quarry was opened about 30 years ago and has been in operation ever since that date. The quantity of glass sand here is practically inexhaustible. It is regarded as one of the best glass sands of Kentucky. Some glass company owned and operated a large sand pit across the Illinois Central tracks almost opposite the Schwindler property for several years. They washed and screened the sand, but when their large storage plant burned down, they abandoned the property. A considerable outcrop of this same sand belt occurs on either side of the Illinois Central track just south of the village of East View.

A sand outcrop appears about one mile northwest of East View toward Stephensburg on both sides of the Illinois Central Railroad. This sand may not be quite as good a glass sand as that at East View, for it carries a little larger percentage of pyrite grains. This property is owned by James M. Dougherty of Cincinnati, O. About one mile south of East View on both sides of the Illinois Central Railroad the sand beds again appear. The depth of the sand here is at least 25 feet, and may be more. The sand is very white. These widely distributed occurrences prove an inexhaustible supply of glass sand in Hardin County.

SOLWAY.

At Solway, on the Enos Cundiff farm, there is reported to be an outcrop of Big Clifty white sand from 50 to 60 feet in thickness

GRAYSON COUNTY.

BIG CLIFTY.

The same friable sandstone that has been so prominent at Tip Top and East View continues into Grayson County, and comprises a part of the cliffs along Clifty Creek over which the Illinois Central Railroad passes. Glass sand can be secured near the railroad along this creek.

WEST CLIFTY.

,The same sandstone appears at West Clifty, but was not closely examined.

LEITCHFIELD.

The author is largely indebted to Mr. John E. Stone, land surveyor of Leitchfield, for the logs of wells driven in Leitchfield, and for his assistance in the field.

In the ravine just east of Leitchfield one-half mile from the court house and on the eastern boundary line of the town of Leitchfield the Big Clifty sands have been obtained and used for plaster. mortar, cement, and concrete. The reddish brown sandstone that belongs to the Chester series and upon which the court house stands is more compact than the Big Clifty sandstone, which around Leitchfield is from 40 to 50 feet in thickness.

Two fine outcrops of the Big Clifty friable sandstone occur on the farm of Jesse C. Lee, one mile northeast of the court house at Leitchfield, 25 rods from the state road leading to Elizabethtown, 40 rods from the Illinois Central Railroad, and on the same grade. These pits were opened up to secure sand for building purposes. The sand varies from white to a yellowish white in color. The grains are medium in size, free from scales of mica, and would make a very good glass sand.

Glass sand occurs on the farm of James Morris about three-fourths of a mile northwest of the court house and one-half of a mile for the Illinois Central Railroad. There is a permanent water supply about one-third of a mile distant for washing the sand. This property is also known as the Hill quarry. The stone extends towards Leitchfield underneath the Hill Cemetery, and appears on both sides of the Hardinsburg road. The sandstone is very friable and yellowish white in color. When washed and screened it would make a very good glass sand.

The Big Clifty sandstone occurs as a glass sand about one-third of a mile northwest of the Hill quarry and on the Falls road between the land owned by Charles S. Stinson and Andrew Chriswell. It occurs on both the north and south side of the road. The sand is very friable and reduces to sand grains as soon as struck with a hammer. The sand varies in color from white to yellowish white. The road passing thru this sand was just being repaired, which gave an excellent opportunity to see fresh exposures of the stone. A permanent water supply exists within one-third of a mile of the sand. At Black Rock Tunnel, four miles west of Leitchfield on the Illinois Central Railroad, the tunnel is supported by brick walls on account of the weakness of the sandstone. This stone is reported to be Big Clifty.

It is interesting to note that there are several gas wells in and around Leitchfield, and that this gas could be used as a fuel in the manufacture of glass from these glass sands.

WELL LOGS.

Hill well, one-half mile east of Leitchfield.

Chester sandstone	18 feet
Kaskaskia limestone	50 feet
Big Clifty sandstone	80 feet

Hunter well, on south side of town.

Chester	wanting
Kaskaskia	35 feet
Big Clifty	40 feet

Allen-Wallace well, three-fourths mile southwest of court house.

Chester lime	18 feet
Marl	22 feet
Chester lime	40 feet
Not sandstone	20 feet
Kaskaskia	55 feet
Big Clifty	55 feet

John Dunn well.

Clay	39 feet
Chester lime	4 feet
Shale and marl	34 feet
Big Clifty	58 feet

About one mile east of the court house an oil well now being drilled passed thru 50 feet of white Big Clifty sand.

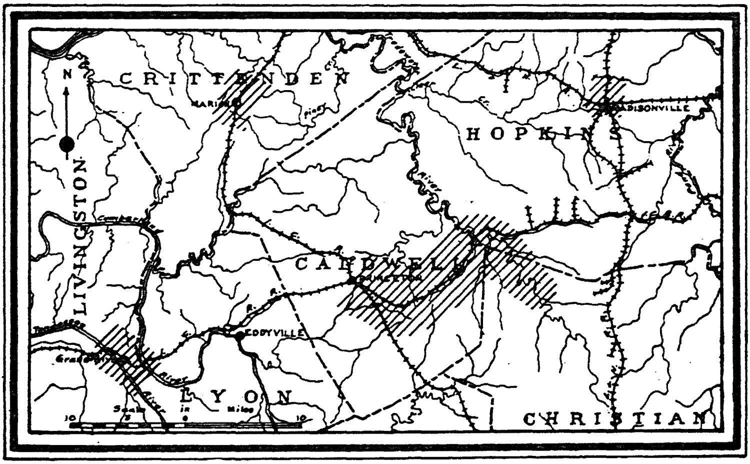
MILLERSTOWN.

In Millerstown some 10 miles southeast of Big Clifty there are two large outcrops of glass sand. These are on the farm of E. F. Aubrey and the adjoining farms.

CHAPTER XV.

GLASS SANDS OF WESTERN KENTUCKY.

Western Kentucky as embraced in this report includes Crittenden, Caldwell, Hopkins and Livingston Counties. They are bordered on the north by Union and Webster Counties; on the east by McLean, Muhlenberg and Christian Counties; on the south by Christian, Trigg and Lyon Counties; on the west by Lyon County and the Ohio River. For further location (See Ills. 21).



(21.) Sectional map showing the distribution of Glass Sands in Western Kentucky.

The glass sands of western Kentucky owe their commercial value to the fact that in ancient seas pure white quartz sands were deposited over extensive areas. These sands were laid down free from clayey matter, free from the hydrated oxides of iron, and free from calcium and magnesium carbonates. The sands were compressed by their own weight and the burden of overlying sediments. They were lifted gently from the floor of the sea into a land mass, and subsequent continental denudation has brought these sand beds into view.

They have now become so disintegrated that under the blow of a hammer they readily reduce to individual sand grains. Many of the beds are so friable that they may be reduced to a pure white quartz sand by crushing them between the fingers. These sand grains are pure white in color, rounded to subangular in form, of uniform size, and remarkably free from any injurious constituent. They are

regarded as most satisfactory glass sands for the manufacture of all kinds of glass, even those which require the greatest care in the selection of the raw material.

To produce such sands care must be taken not to contaminate the sand with the burden of overlying top soil or iron stained sands whose yellowish brown color has been produced by an infiltration of iron oxides from the soil.

CRITTENDEN COUNTY.

MARION.

Most excellent glass sand occurs as a consolidated sandstone that is exceedingly friable at what is known as the Lemuel Clark sand pits about three-fourths of a mile east of the court house at Marion and about one-half mile east of the station on the Illinois Central Railroad.

These sands are pure white or nearly pure white in color in the whitest portions of the beds. Where the blocks have long been exposed to the action of ground waters they are stained yellowish white by infiltrating hydrated oxides of iron. These blocks in the adjacent ravines are sometimes red from the character of these iron bearing solutions. Sometimes when the surface of these blocks is brown, or yellowish brown, the interior of the block is yellowish white, showing that the effect of the iron is largely confined to the surface.

There are three openings of this sandstone available for inspection. Two of them are on the farm owned by Lemuel Clark and his son. One of these is situated about 10 rods from the main road, and the other about 15 rods. Glass sand has been shipped from these sand pits to Evansville, Indiana. It has been used in the manufacture of brick for consumption in Marion. Also as a general building sand.

The third pit is on land owned by Dr. O. C. Cook, and the quarry opening is situated about 20 rods north of the second Baptist Church of Marion. The sandstone was here quarried for base courses, curbing, paying, and flagging stone. The sandstone extends all the way from the abandoned Cook quarry to the Clark sand pits. The general direction of the formation is apparently southwesterly. This sandstone covers more than 50 acres. It has been traced southwesterly upon adjacent farms. There appears to be as much of this glass sand upon the farm of J. R. Summerville as there is on the farm of Lemuel Clark. (See Ills. 22).

This consolidated sandstone consists of even textured, fine to medium grained sand, bound together so loosely that a single blow of a sledge hammer will reduce large blocks to sand. It is a little too resistant to be broken up into sand by a jet of water, like the sand at Tip Top in Hardin County Scales or flakes of muscovite are exceedingly rare, and no grains of feldspar were observed. This sandstone is somewhat stained with iron oxides on the surface where

(22.) Crittenden County white sand grains showing exact size.

percolating waters have carried iron bearing solutions between the beds of sandstone and along the joint planes. Sometimes near the surface the stone is bounded with yellowish white and white layers in alternation, but the remainder of the block will be white.

The thickness of the formation varies from 30 to 40 feet, and in many places it may be much thicker. On the north brow of the hill a shaft has been sunk 19 feet thru the sandstone to a bed of limestone. From this as a base line, a thickness of 40 feet was platted for two different outcrops. There is at least 5 acres of glass sand around the sand pits, while on the Clark, Cook and Summerville farms combined there are more than 50 acres of excellent glass sand. There is also a supply of water in the valley just a few rods from the sand pits that can be used in washing the sand. According to A. M. Shelby, field Superintendent of the Kentucky Fluor Spar Company, a pure white quartz sandstone in an inexhaustible quantity forms bluffs from 60 to 80 feet in height about two miles north of Marion. The quality of these sands makes them well suited for the manufacture of glass.

SALEM.

A large supply of white to yellowish white sandstone occurs on the farm of J. Hardin, about one mile northeast of Salem.

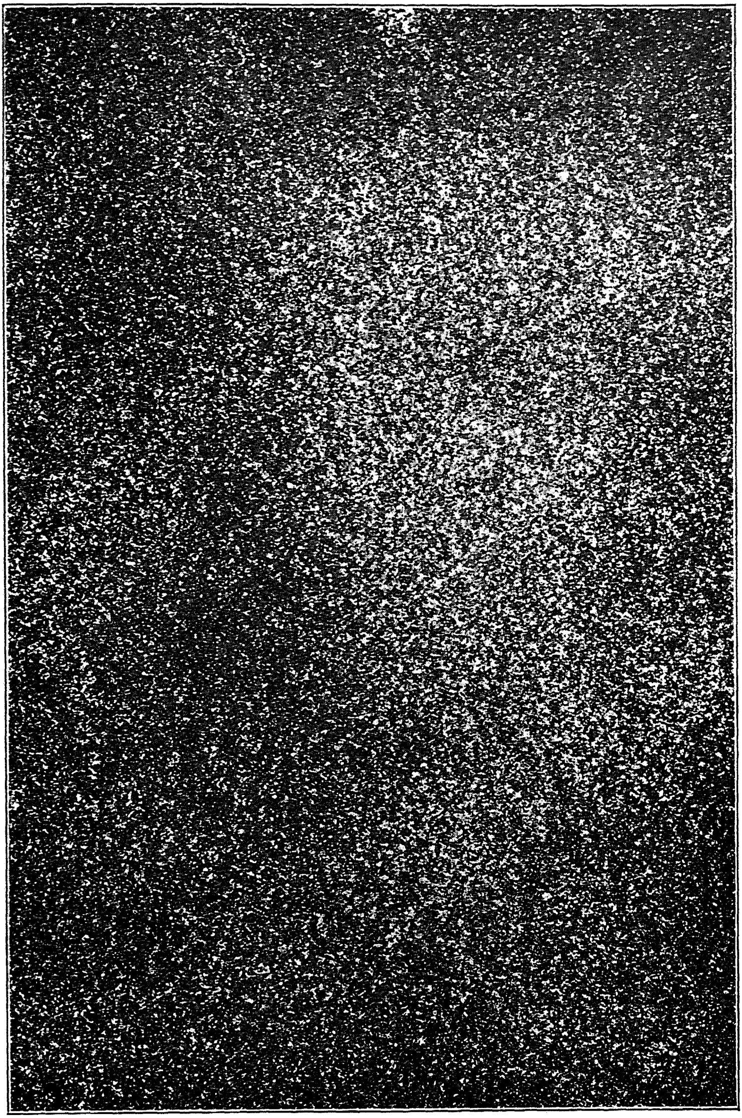
CALDWELL COUNTY.

PRINCETON.

On the farm of W. F. Holeman, 601 East Market street, Princeton, there occurs a bed of consolidated sand or sandstone that is the equal of, if not superior to, any other glass sand in Kentucky. The sandstone quarry is situated about one mile northeast of the court house and about three-fourths of a mile from the Illinois Central Railroad. There is plenty of water about 100 rods away for washing the sand. Yet, this sand is so pure that if care was taken in removing the over burden of soil which is very shallow, and the few feet of iron stained sandstone beneath the soil and overlying the white quartz sand, the product would scarcely need washing.

The sandstone is so friable that large blocks fall to a powder when struck with a sledge hammer. The lower 30 feet is pure white when dry or nearly pure white in certain sections. The sand grains are of uniform size, fine to medium, and round to subangular in shape. The upper 20 feet is slightly iron stained on the surface, but often white to yellowish white when broken open. The quarry opening is about 150 feet in length. This sandstone is regarded as belonging to the Big Clifty, for it bears all the earmarks of the Big Clifty as it appears at East View, Leitchfield, and Marion.

The old Thomas Young quarry is now owned by W. F. Holeman. It is situated about one-fourth mile toward Princeton from the quarry already described. The sandstone is of about the same grade with perhaps a larger percentage of yellowish white sand. These two quarries are probably connected under a mantle of comparatively thin soil. If so, then the area covered by this glass sand would not be less than 40 acres. (See Ills. 23).



(23.) Caldwell County white sand grains showing exact size.

CEDAR BLUFFS.

The old Hunter sandstone quarry is situated about one mile from Cedar Bluffs, and is now owned by L. C. O'Hara. This sand is reported to be yellowish white at the top with some 20 feet or

more exposed in the quarry face, and with 20 feet of white or yellowish white sand that was not quarried on account of its brittleness. This quarry is further located on the Sand Lick road.

HOPKINS COUNTY.

DAWSON SPRINGS.

It seems impracticable to discuss the glass sands of Hopkins County without including some of the glass sands of Caldwell County, because the formation is continuous from the Dawson Springs area southward toward Princeton in Caldwell County. The Tradewater River makes the boundary between the two counties.

Glass sands occur as a consolidated sandstone about one-fourth mile south of Dawson Springs and on either side of the Illinois Central Railroad. In the first rock cut south of the station there is a pronounced fault in the rocks and no commercial glass sands were recognized north of this fault.

The tunnel on the Illinois Central Railroad one-fourth mile below Dawson Springs passes thru the sandstone that is considered a fairly satisfactory glass sand. Both north and south of the tunnel the sandstone is yellowish white, being slightly banded with iron stained layers of quartz. Samples could be and were collected that were almost a pure white. The analysis of samples sent to the State Experiment Station will reveal whether this is simply an iron oxide stain or whether there is an appreciable iron content in the sandstone. The whitest of this sand occurs just south of the tunnel, and on the left of the Illinois Central Railroad, and furthermore between the railroad and the cave some 30 or 40 rods to the left of the railroad. This sand is very satisfactory for the manufacture of glass.

The same formation extends a long distance beyond the cave with sufficient freedom from iron to be used as a glass sand. It also extends southward toward Claxton on the Illinois Central Railroad for a distance of at least 5 miles. Quartz pebbles are sometimes found in this friable sandstone. These pebbles strongly suggest that these white and yellowish white sandstones belong to the Pottsville series and are of Pennsylvanian age. The supply of glass sand here is practically inexhaustible. The Tradewater River would furnish all the water needed to wash the sand. The Illinois Central Railroad passes thru the glass sand deposit.

On the farm of Travis H. O'Brien about 200 yards from the village line and three-fourths of a mile from the railroad station there occurs a large deposit of yellowish sand that has been extensively used for plaster, mortar, cement, and concrete. According to Mr. O'Brien this sand covers 40 acres and a test hole went down thru 100 feet of sand without striking bottom. For glass sand this material would require careful washing.

On property owned by the Rev. J. W. Carlyle there is a large tonnage of very white sand usually regarded as the whitest of the Dawson Springs sands and a good glass sand.

On the O. P. Ridley farm about 1 mile from the station medium white sands are said to occur in considerable quantity.

MADISONVILLE.

According to J. M. Ashby of Madisonville there is a large amount of white sand located about 50 yards from the Louisville & Nashville Railroad and about 2 miles due north of the station. It is furthermore located on the Hanson road on the farm known as the James Woodman farm.

An analysis of a white sandstone from Madisonville collected by E. G. McLeoud several years ago gave 98.68 per cent of silica and only .15 per cent of iron oxide. This appears to be the sand referred to in the analysis. The material corresponding with the above analysis would make an excellent glass sand.

About 100 rods south of Madisonville along the Louisville & Nashville Railroad there occurs a yellowish white micaceous sandstone that appears to be too rich in its iron content, and also in its mica content, to be successfully utilized in the manufacture of glass.

LIVINGSTON COUNTY.

GRAND RIVERS.

Several sand deposits were found at or near Grand Rivers.

(1) One-fourth mile southeast of the Illinois Central station. This sand is iron stained and aluminous, and would require most careful washing.

(2) North of the Illinois Central station one-half mile on land owned by Haggard Nichols. This sand is yellowish white in color and used locally as a building sand.

(3) One-fourth mile from the plant of the Sewanee Iron Company there is a very large bed of molding sand. This sand is sharp and angular in form, yellowish white in color, and contaminated with scales of mica. It has been used for many years by the Sewanee Iron Company as a molding sand and for the beds in which the pig iron is run. It can be used as a glass sand in the manufacture of green bottles.

(4) Two miles below Grand Rivers on land owned by Jefferson Walker. This sand is also yellowish white in color and somewhat aluminous. These sands are all better classified as molding sands and building sands than as glass sand, even though green bottle glass could be manufactured from some of them.

GRAVEL SWITCH.

Gravel Switch is on the Illinois Central Railroad about two miles below Grand Rivers. There is not only a flag stop by that name, but a switch that sends the freight trains to exceedingly valuable gravel beds. The gravel beds are more than 1,000 feet in length and 50 feet in thickness above the present level of the railroad tracks. (1) There is one gravel bed more than 1,000 feet in length close to the Gravel Switch which has been temporarily abandoned. (2) A second gravel bed just above Gravel Switch. (3) A third gravel bed of more than 1,000 feet in length now operated by the Illinois Central Railroad. This gravel bed from borings has been proven to be 100 feet thick and the Illinois Central intends soon to start working on a level 50 feet below the present level and give a 100 foot working face.

The gravel consists largely of quartz pebbles cemented together with a white clay. The gravel is broken down by explosives and loaded by steam shovels into cars for shipment as railroad ballast and for the manufacture of concrete. When this product is used as ballast it soon becomes as hard as concrete. When shipped to Birmingham, Alabama, it becomes hard like cement before reaching its destination. It is the largest and best gravel deposit known by the author. The Illinois Central bought 60 acres of this gravel from W. C. Bell of Grand Rivers. He still owns more gravel areas.

There is also said to be 50 acres or more of this same type of sand owned by S. E. Sexton. This material is of great value in the manufacture of permanent roads, for it has high resistance to abrasion and high cementing power. A sample of this gravel was carefully washed to study its sand content. While glass sand can be washed from the gravel it is not recommended.

CHAPTER XVI.

MISCELLANEOUS SAND DEPOSITS.

EDMONSON COUNTY.

MAMMOTH CAVE.

The material reported as glass sand in Edmonson County between Glasgow Junction and Mammoth Cave consists of a much decomposed reddish sandstone that overlies the St. Louis limestone.

It is too rich in its iron content for the manufacture of the better grades of glass, and of too small an area to compete successfully with the larger areas of Carter, Hardin, Grayson, Crittenden and Caldwell Counties.

BARREN COUNTY.

GLASGOW.

The material reported as white glass sand from the higher altitudes of Glasgow consists of flint and chert residues of disintegration from the cherty layers of the corniferous limestone. Often the chert when weathered is an opaque white. It is hard, compact, and does not break up readily into uniform sand grains. It can be reduced to a product that would pass a 60 mesh sieve and find some application, but if reduced to 150 mesh sieve it would be expensive to prepare. Such material has been used as an adulterant of paint and soap as well as in the manufacture of glass.

JACKSON PURCHASE.

McCRACKEN COUNTY.

PADUCAH.

Mr. R. H. Noble, President of the Ohio River Sand and Gravel Company of Paducah, writes: "We pump all our sands from the Ohio River and our products are mostly used for building purposes and concrete work. We do not experience any difficulty in getting all the sand we need, for the supply of Ohio River sand at Paducah is inexhaustible." The sands above referred to may be screened to a 60 mesh sieve and used as glass sands. The deposits may be classified as a glass sand reserve.

Many inquiries were made for the location of white glass sands in the Jackson Purchase, but no white sands could be located within 8 miles of the railroad or the Ohio River. This distance from points of shipment militates against the use of such remote sand deposits as glass sands.

HART COUNTY.

MUNFORDVILLE.

According to J. M. Campbell, attorney and counselor at law, Leitchfield, there occurs on the Ridge road from Cub Run to Munfordville, the county seat of Hart County, what is known as the Sand Hills. These sand deposits are considered to be in tonnage about five time that of the Tip Top and East View deposits combined. They are white in color and most excellent glass sands, but unfortunately they are situated four miles from the nearest railroad.

CLARK COUNTY.

WINCHESTER.

According to Mr. E. S. Perrie of Winchester there is a large deposit of glass sand or friable micaceous sandstone not far from Winchester that would make a good glass sand. The exact location of this sand was not divulged.

WOLFE COUNTY.

TORRENT.

According to Daniel J. Jones there occurs at Torrent along the line of the Lexington & Eastern Railroad a heavy bedded and massive sandstone that is fairly white in color and would make a possible glass sand.

CHAPTER XVII.

ANALYSES OF GLASS SANDS AND SANDSTONES.

The analyses of glass sands and sandstones as they appear in this report were made by or under the direction of Dr. Robert Peter and Dr. A. M. Peter, Directors of the State Experiment Station, Lexington, Kentucky. Wherever an exception to this rule appears the name of the analyst is given provided the name is known.

Chemical analyses Nos. 1-28 inclusive in this report were made by Messrs. Averitt and Iler at the Kentucky Experiment Station, Lexington, Ky. A few analyses of glass sands other than those found in Kentucky are appended for comparison.

CARTER COUNTY.

Analysis No. 1.

Laboratory No. G-3916, labeled "No. 1. White sandstone somewhat banded with brownish layers of iron-stained quartz. From Olive Hill, Carter County, Ky. C. H. Richardson."

Sample, a 20-oz. lump of light cartridge-buff colored, soft, fine grained stone.

Analysis of the air-dried sample.	Per cent.
Silica, SiO_2	97.92
Ferric oxide, Fe_2O_3	0.18
Alumina, Al_2O_3	1.81
Titanium dioxid, TiO_2	0.11
Moisture at 104° C.	0.08
Loss on burning	0.52
Total	100.62

Analysis No. 2.

Laboratory No. G-3917, labeled "No. 2. White sandstone slightly tinted yellow by iron stain. From Tygart, Carter Co., Ky. C. H. Richardson."

Sample, a 12-oz. lump, much like G-3916, but harder.

Analysis of the air-dried sample.	Per cent.
Silica, SiO_2	96.83
Ferric oxid, Fe_2O_3	0.18
Alumina, Al_2O_3	2.55
Titanium dioxid, TiO_2	0.32
Moisture at 104° C.	0.08
Loss on burning	0.65
Total	100.61

Analysis No. 3.

Laboratory No. G-3918, labeled "No. 3. Yellowish-white, fine grained, even textured sandstone from Globe, Carter Co., Ky. This

sample is overlain by No. 4 which is somewhat coarser in texture than No. 3 and appears to be richer in its iron content. C. H. Richardson."

Sample, an 8-oz. lump of fine-grained, cartridge-buff colored soft stone.

Analysis of the air-dried sample.	Per cent.
Silica, SiO_2	96.89
Ferric oxid, Fe_2O_3	0.16
Alumina, Al_2O_3	2.41
Titanium dioxid, TiO_2	0.40
Moisture at 104° C.	0.10
Loss on burning	0.68
Total	100.64

Analysis No. 4.

Laboratory No. G-3919, labeled "No. 4. Yellowish-brown, even grained, medium textured sandstone from Globe, Carter Co., Ky. This sample is taken directly from the surface face of a cliff some half mile in length and some 30 ft. in height. C. H. Richardson."

Sample, 3-oz. lump of rather coarse grained, soft, light-brownish, very friable stone.

Analysis of the air-dried sample.	Per cent.
Silica, SiO_2	98.84
Ferric oxid, Fe_2O_3	0.12
Alumina, Al_2O_3	0.92
Titanium dioxid, TiO_2	0.04
Moisture at 104° C.	----------
Loss on burning	0.20
Total	100.12

PIKE COUNTY.

Analysis No. 5.

Laboratory No. G-3923, labeled "No. 5. River sand from the Levisa river some 20 rods below the bridge over the Levisa at Pikeville, Pike County, Ky. C. H. Richardson."

Sample, about 2 ozs. of brown, rather fine-grained sand, containing some particles of coal and some mica scales.

Analysis of the air-dried sample.	Per cent.
Silica, SiO_2	90.54
Ferric oxid, Fe_2O_3	1.22
Alumina, Al_2O_3	3.96
Titanium dioxid, TiO_2	0.20
Moisture at 104° C.	0.12
Loss on burning	1.40
Total	97.44

FLOYD COUNTY.

Analysis No. 7.

Laboratory No. G-3924, labeled "No. 6. Unwashed river sand, Middle Creek, Prestonsburg, Floyd County, Ky. C. H. Richardson."

Sample, about 2 ozs. of brown, rather fine-grained sand.

Analysis of the air-dried sample.	Per cent.
Silica, SiO_2	93.22
Ferric oxid, Fe_2O_3	1.18
Alumina, Al_2O_3	3.16
Titanium dioxid, TiO_2	0.18
Moisture at 104° C.	0.03
Loss on burning	0.90
Total	98.67

Analysis No. 8.

Laboratory No. G-3924-A. A portion of G-3924 was washed by stirring up with water, allowing to settle a moment and pouring off the muddy liquid, repeating the process until the water came off clear. The washed sand was then dried and analyzed. It amounted to 96 per cent of the original portion; i. e., the loss in washing was 4 per cent.

Analysis of the air-dried sample.	Per cent.
Silica, SiO_2	95.00
Ferric oxid, Fe_2O_3	1.06
Alumina,, Al_2O_3	2.33
Titanium dioxid, TiO_2	0.15
Moisture at 104° C.	0.01
Loss on burning	0.66
Total	99.21

Analysis No. 9

Laboratory No. G-3925, labeled "No. 8. River sand from Beaver Creek, on meander above bridge. Floyd County, Ky. C. H. Richardson."

Sample, about 2 ozs. of brown, rather fine-grained sand.

Analysis of the air-dried sample.	Per cent.
Silica, SiO_2	95.24
Ferric oxid, Fe_2O_3	1.09
Alumina, Al_2O_3	2.85
Titanium dioxid, TiO_2	0.18
Moisture at 104° C.	0.07
Loss on burning	0.90
Total	100.33

JOHNSON COUNTY.

Analysis No. 11.

Laboratory No. G-3926, labeled "No. 9. Unwashed sand on Levisa River from mouth of Paint Creek, Paintsville, Johnson County, Ky. C. H. Richardson."

Sample, 4 ozs. of clean-looking, light brown, fine sand.

Analysis of the air-dried sample.	Per cent.
Silica, SiO_2	93.52
Ferric oxid, Fe_2O_3	1.65
Alumina, Al_2O_3	3.24
Titanium dioxid, TiO_2	0.19
Moisture at 104° C.	0.03
Loss on burning	1.10
Total	99.73

Analysis No. 12.

Laboratory No. G-3927, labeled "No. 10. Compact, micaceous, drab-colored sandstone from Paintsville, Johnson County, Ky. C. H. Richardson."

Sample, an 8-oz. lump of pale neutral-gray colored stone showing black and dark brown specks and occasional small mica scales. Rather soft.

Analysis of the air-dried sample.	Per cent.
Silica, SiO_2	75.98
Ferric oxid, Fe_2O_3	3.30
Alumina, Al_2O_3	12.36
Titanium dioxid, TiO_2	0.70
Moisture at 104° C.	0.09
Loss on burning	3.00
Total	95.43

BOYD COUNTY.

Analysis No. 13.

Laboratory No. G-3928, labeled "No. 11. Brittle, yellowish-white sandstone from Fourth Ward, Catlettsburg, Boyd County, Ky. C. H. Richardson."

Sample, an 8-oz. lump of friable, cream-buff colored, medium grained stone, splitting into irregular layers. Looks like a weathered sample.

Analysis of the air-dried sample.	Per cent.
Silica, SiO_2	89.55
Ferric oxid, Fe_2O_3	1.12
Alumina, Al_2O_3	6.21
Titanium dioxid, TiO_2	0.20
Moisture at 104° C.	0.27
Loss on burning	1.73
Total	99.08

PIKE COUNTY.

Analysis No. 6.

Laboratory No. G-3929, labeled "No. 12. Sandstone near east end of bridge over the Levisa at Pikeville, Pike County, Ky. C. H. Richardson."

Sample, a 6-oz. lump of pallid neutral gray, rather hard, rather fine grained stone containing frequent bright mica scales and greenish and brownish particles.

Analysis of the air-dried sample.	Per cent.
Silica, SiO_2	78.74
Ferric oxid, Fe_2O_3	2.11
Alumina, Al_2O_3	11.56
Titanium dioxid, TiO_2	0.31
Moisture at 104° C.	0.23
Loss on burning	2.83
Total	95.78

FLOYD COUNTY.

Analysis No. 10.

Laboratory No. G-3930, labeled "No. 13. Hard, drab colored micaceous sandstone from bluff about 30 rods below Banner, Floyd County, Ky. C. H. Richardson."

Sample, a 5-oz. lump of pallid, neutral gray, fine-grained stone containing greenish specks and some mica scales.

Analysis of the air-dried sample.	Per cent.
Silica, SiO_2	76.76
Ferric oxid, Fe_2O_3	1.86
Alumina, Al_2O_3	12.58
Titanium dioxid, TiO_2	0.66
Moisture at 104° C.	0.16
Loss on burning	2.97
Total	94.99

LAWRENCE COUNTY.

Analysis No. 14.

Laboratory No. G-3931, labeled "No. 14. River sand from the junction of the Tug and Levisa Rivers, Louisa, Lawrence County, Ky. Collected July 26, 1920. C. H. Richardson."

Sample, 4 ozs. of light brown sand. A few mica scales and particles of coal.

Analysis of the air-dried sample.	Per cent.
Silica, SiO_2	90.14
Ferric oxid, Fe_2O_3	1.20
Alumina, Al_2O_3	4.48
Titanium dioxid, TiO_2	0.44
Moisture at 104° C.	----------
Loss on burning	1.65

ROWAN COUNTY.

Analysis No. 15.

Laboratory No. G-3932, labeled "No. 15. Sandstone from Blue Grass Quarries Company's quarry at Freestone, Rowan County, Ky. Collected July 29, 1920. C. H. Richardson."

Sample, a 22-oz. lump of pallid neutral gray, fine-grained, firm, soft stone.

Analysis of the air-dried sample.	Per cent.
Silica, SiO_2	85.52
Ferric oxid, Fe_2O_3	1.79
Alumina, Al_2O_3	6.99
Titanium dioxid, TiO_2	0.70
Moisture at 104° C.	0.17
Loss on burning	2.32
Total	97.49

CARROLL COUNTY.

Analysis No. 16.

Laboratory No. G-3933, labeled "No. 16. Unwashed river sand from mouth of Kentucky River, Carrollton, Carroll County, Ky. Grobmyer Coal Co. Aug. 3, 1920. C. H. Richardson."

Sample, 2-ozs. rather coarse sand containing red, brown and white grains.

Analysis of the air-dried sample.	Per cent.
Silica, SiO_2	85.30
Ferric oxid, Fe_2O_3	1.63
Alumina, Al_2O_3	4.41
Titanium dioxid, TiO_2	0.16
Moisture at 104° C.	0.09
Loss on burning	3.54
Total	95.13

Analysis No. 17.

Laboratory No. G-3934, labeled "No. 17. Unwashed delta sand from Carrollton, Carroll County, Ky. Carrollton Brick Company. Aug. 3, 1920. C. H. Richardson."

Sample, 3 ozs. much like No. 16.

Analysis of the air-dried sample.	Per cent.
Silica, SiO_2	87.64
Ferric oxid, Fe_2O_3	1.90
Alumina, Al_2O_3	4.38
Titanium dioxid, TiO_2	0.18
Moisture at 104° C.	0.11
Loss on burning	3.00
Total	97.21

Analysis No. 17-A.

Laboratory No. G-3935, labeled "No. 18. Dredge washed sand, screened to 60 mesh, from Kentucky side of Ohio River, Carrollton, Carroll County, Ky. From The Kentucky & Ohio Transportation Co. Aug. 3, 1920. C. H. Richardson."

Sample, 4 ozs. of clean-looking, light brown, fine sand.

Analysis of the air-dried sample.	Per cent.
Silica, SiO_2	92.25
Ferric oxid, Fe_2O_3	1.28
Alumina, Al_2O_3	3.11
Titanium dioxid, TiO_2	0.21
Moisture at 104° C.	----------
Loss on burning	1.00
Total	97.85

Analysis No. 18.

Laboratory No. G-3935, labeled "No. 18. Dredge washed sand, screened to 60 mesh, from Kentucky side of Ohio River, Carrollton, Carroll County, Ky. From The Kentucky & Ohio Transportation Co. Aug. 3, 1920. C. H. Richardson."

Sample, 4 ozs. of clean-looking, light brown, fine sand.

Analysis of the air-dried sample.	Per cent.
Silica, SiO_2	92.25
Ferric oxid, Fe_2O_3	1.28
Alumina, Al_2O_3	3.11
Titanium dioxid, TiO_2	0.21
Moisture at 104° C.	----------
Loss on burning	1.00
Total	97.85

HARDIN COUNTY.

Analysis No. 19.

Laboratory No. G-3935, labeled "No. 24, glass sand collected Aug. 12, 1920, at East View, Hardin County, Ky., by C. H. Richardson."

Sample, about 4 ozs. of very fine-grained, nearly white sand.

Analysis of the air-dried sample.	Per cent.
Silica, SiO_2	97.52
Ferric oxid, Fe_2O_3	0.48
Alumina, Al_2O_3	0.47
Titanium dioxid, TiO_2	0.13
Moisture at 104° C.	0.06
Loss on burning	0.59
Total	99.25

Analysis No. 19-A.

Laboratory No. G-3951, labeled "No. 19, white glass sand collected Aug. 6, at Tip Top, Hardin County, Ky. C. H. Richardson."

Sample, an 8 oz. sample of nearly white, clean-looking, fine-grained sand.

Analysis of the air-dried sample.	Per cent.
Silica, SiO_2	98.26
Ferric oxid, Fe_2O_3	0.43
Alumina, Al_2O_3	1.09
Titanium dioxid, TiO_2	trace
Moisture at 104° C.	0.06
Loss on burning	0.26
Total	100.10

CALDWELL COUNTY.

Analysis No. 20.

Laboratory No. G-3936, labeled "No. 20, white sandstone from farm of W. F. Holeman, Princeton, Caldwell County, Ky. Collected Aug. 15, 1920. C. H. Richardson."

Sample, a 23-oz. lump of pure-looking, nearly white, soft, friable fine-grained sandstone.

Analysis of the air-dried sample.	Per cent.
Silica, SiO_2	97.84
Ferric oxid, Fe_2O_3	0.32
Alumina, Al_2O_3	0.62
Titanium dioxid, TiO_2	trace
Moisture at 104° C	....
Loss on burning	0.33
Total	99.11

HOPKINS COUNTY.

Analysis No. 21.

Laboratory No. G-3937, labeled "No. 21, yellowish-white sandstone from railroad cut 100 rods south of station on I. C. R. R., Dawson Springs, Hopkins County, Ky. Collected Aug. 17, 1920. C. H. Richardson."

Sample, an 18-oz. sample, part very soft, friable, fine-grained stone ranging in color from nearly white to light buff, and part sand. Magnet withdrew a very few very small, black, brittle particles.

Analysis of the air-dried sample.	Per cent.
Silica, SiO_2	97.76
Ferric oxid, Fe_2O_3	0.53
Alumina, Al_2O_3	0.87
Titanium dioxid, TiO_2	0.08
Moisture at 104° C.	....
Loss on burning	0.38
Total	99.62

CLARK COUNTY.

Analysis No. 26.

Laboratory No. G-3945, labeled "No. 26, yellowish-white, micaceous glass sand collected by E. S. Perrie of Winchester, Ky. Exact locality unknown to Charles H. Richardson, Assistant Geologist."

Sample, about 4 ozs. of gray, micaceous sand or very soft sandstone, loosely cemented with clay. The lumps can be crushed between the fingers.

Analysis of the air-dried sample.	Per cent.
Silica, SiO_2	90.02
Ferric oxid, Fe_2O_3	0.55
Alumina, Al_2O_3	5.61
Titanium dioxid, TiO_2	0.22
Moisture at 104° C.	0.04
Loss on burning	1.03
Total	97.47

LAUREL COUNTY.

Analysis No. 27.

Laboratory No. G-3946, labeled "No. 27, tan colored, micaceous glass sand from Lily, Laurel County, Ky. Collected by C. A. McKnight, Aug., 1920. C. H. Richardson."

Sample, about 3 ozs. of buff colored, fine sand containing a few scales of mica.

Analysis of the air-dried sample.	Per cent.
Silica, SiO_2	94.54
Ferric oxid, Fe_2O_3	0.58
Alumina, Al_2O_3	2.82
Titanium dioxid, TiO_2	0.18
Moisture at 104° C.	0.09
Loss on burning	0.92
Total	99.13

CRITTENDEN COUNTY.

Analysis No. 28.

Laboratory No. G-3921, labeled "Glass sand from the Chester series, from farm of Lem Clark, one-half mile from Marion, Crittenden County, Ky. Collected by W. R. Jillson, July 15, 1920."

Sample, a 2½ lb. lump of soft, fine-grained, nearly white stone.

Analysis of the air-dried sample.	Per cent.
Silica, SiO_2	98.39
Ferric oxid, Fe_2O_3	0.14
Alumina, Al_2O_3	1.04
Titanium dioxid, TiO_2	0.15
Moisture at 104° C.	0.07
Loss on burning	0.34
Total	100.13

GRAYSON COUNTY.

Analysis No. 28-A.

Laboratory No. G-3952, labeled "No. 22, glass sand collected Aug. 10, 1920, on the farm of Jesse C. Lee, Leitchfield, Grayson County, Ky., by C. H. Richardson."

Sample a 12-oz. lump of soft friable fine-grained, nearly white stone streaked with reddish, and with occasional small mica scales.

Analysis of the air-dried sample.	Per cent.
Silica, SiO_2	96.66
Ferric oxid, Fe_2O_3	0.26
Alumina, Al_2O_3	1.86
Titanium dioxid, TiO_2	0.16
Moisture at 104° C.	0.20
Loss on burning	0.75
Total	99.89

Analysis No. 28-B.

Laboratory No. G-3953, labeled "No. 23, glass sand collected on the farm of James Morris, Aug. 11, 1920. Leitchfield, Grayson County, Ky. C. H. Richardson."

Sample, a 20-oz lump, similar to No. 3952 but with more of the reddish coloration and less friable.

Analysis of the air-dried sample.	Per cent.
Silica, SiO_2	97.36
Ferric oxid, Fe_2O_3	0.32
Alumina, Al_2O_3	1.34
Titanium dioxid, TiO_2	trace
Moisture at 104° C.	0.09
Loss on burning	0.55
Total	99.66

Analysis No. 28-C.

Laboratory No. G-3954, labeled "No. 25, glass sand collected on the Falls Road, Leitchfield, Grayson County, Ky. C. H. Richardson."

Sample very similar to No. 3952.

Analysis of the air-dried sample.	Per cent.
Silica SiO_2	98.18
Ferric oxid, Fe_2O_3	0.38
Alumina, Al_2O_3	0.90
Titanium dioxid, TiO_2	trace
Moisture at 104° C.	0.06
Loss on burning	0.36
Total	99.88

The remainder of the analyses in this chapter were either taken directly from the records in the office of Dr. A. M. Peter, Lexington, Ky., or secured from the various factories visited.

CARTER COUNTY.

Analysis of washed glass sand from Lawton, Kentucky, as furnished by the Camp Glass Works of Lawton, Carter County, Kentucky:

Analysis No. 29.

Silica, SiO_2	99.45
Ferric oxide, Fe_2O_3	.04
Alumina, Al_2O_3	tr
Lime, CaO	tr
Magnesia, MgO	tr
Moisture, H_2O	.41
	100.00

Analysis of sample washed sand from Lawton, Kentucky, made by Dr. A. M. Peter:

Analysis No. 30.

Silica. SiO_2	99.05
Ferric oxide, Fe_2O_3	.13
Alumina, Al_2O_3	.39
Lime, CaO	.03
Moisture, H_2O	.08
Ignition	.18
	99.87

GRAYSON AND OHIO COUNTIES.

Sample from Horse Branch on the Elizabethtown & Paducah R R. Border of Grayson and Ohio Counties.

Analysis No. 31.

Sand and insoluble silicates	87.700
Fe_2O_3, Al_2O_2	7.040
CaO	.100
MgO	.245
P_2O_5	.370
SO_3	.049
K_2O	.975
Na_2O	.401
H_2O	3.000
	99.880

This sandstone would undoubtedly answer well in the manufacture of common glass.

NICHOLAS COUNTY.

Sample from Blue Lick Battle Ground.

Analysis No. 32.

Sand and insoluble silicates	93.390
Fe_2O_3, Al_2O_3, MnO_2	4.140
Carbonate of lime	.113
$MgCO_3$	.199
P_2O_5	.092
H_2SO_4	.076
K_2O	.202
Na_2O	.121
H_2O & loss	1.667
	100.000

The presence of this sandstone as a substratum at the Blue Lick Springs is the reason for the sterility and paucity of soil which has generally been attributed by early observers to the trampling of the herds of buffalo which formerly frequented the beds.

MORGAN COUNTY.

Sample sent by Dr. S. R. Collier, West Liberty.

Analysis No. 33.

SiO_2	92.00
Fe_2O_3	1.92
Al_2O_3	2.08
CaO	none
MgO	.51
K_3O	.51
Na_2O	.61
TiO_3	tr
Ingition	.95
	98.58

Not pure enough for a good glass sand.

West Liberty, near Cannel City.

Analysis No. 34.

SiO_2	96.03
Fe_2O_3	.36
Al_2O_3	2.93
	99.32

The low percentage of iron would indicate that this is a very good glass sand.

Long Branch, sample near head of Long Branch, Morgan County.

Analysis No. 35.

SiO_2	91.86
Fe_2O_3	.34
Al_2O_3	5.50
	97.70

The material contains also a little lime, magnesia and combined water which were not determined.

CARTER COUNTY.

Glass sand sent for analysis by Dr. G. R. Logan, Enterprise.

Analysis No. 36.

(I) Soft white sandstone.	
SiO_2	97.73
Fe_2O_3	.12
(II) Soft brownish sandstone.	
SiO_2	97.49
Fe_2O_3	.66
(III) Fine grained soft sandstone.	
SiO_2	97.98
Fe_2O_3	.20

These analyses are very good for unwashed sand.

Sample No. I is the best and is of excellent quality.

Sample No. II would do for green glass.

Sample No. III is nearly as good as No. I.

CALLOWAY COUNTY.

White sand sent by Conn Linn, Murray.

Analysis No. 37.

SiO_2	98.84
Fe_2O_3, Al_2O_3	.50
CaO	.20
MgO	none
TiO_2	.19
Moisture	.12
Ignition	.15
	100.00

A very good quality of sand, suitable for glass sand or any use where purity is desired.

CLARK COUNTY.

Sample sent to Prof. Anderson by the Winchester Granite Brick Company, Winchester.

Analysis No. 38.

SiO_2	96.67
Fe_2O_3	.48
Al_2O_3	1.81
CaO	.02
MgO	.11
Moisture	.03
Ignition	.72
	99.84

Alkalies were not determined, but they can be present only in traces, if at all.

OHIO COUNTY.

Sample sent by J. F. Jackson, Rockport.

Analysis No. 39.

SiO_2	97.39
Fe_2O_3	.36
Al_2O_3	.94
CaO	.22
MgO	tr
Moisture	.18
Ignition	.49

This is a fair quality of sand, would make window glass, bottles, etc.

MAGOFFIN COUNTY.

Sand labeled by J. C. Wheeler, Wheelersburg.

Analysis No. 40.

SiO_2	93.88
Fe_2O_3	.18
Al_2O_3	3.08
CaO	.34
MgO	.07
K_2O	1.82
Na_2O	tr
TiO_2	.24
Moisture	.06
Ignition	1.14
	100.81

This is a medium quality of glass sand. The percentage of alumina is larger than desirable for the best quality and the silica is lower.

HOPKINS COUNTY.

Sample sent by E. G. McLeod, Madisonville.

Analysis No. 41.

SiO_2	98.68
Fe_2O_3	.15
Al_2O_3	.17
CaO	.33
Ignition	.44
	99.79

This material is very pure and should be an excellent glass sand.

JEFFERSON COUNTY.

Sample sent by McAllister & Co., Louisville.

Analysis of air dried sample.

Analysis No. 42.

SiO_2	88.46
Fe_2O_3	.88
Al_2O_3	7.25
CaO	none
MgO	tr
K_2O	.37
Na_2O	.18
TiO_2	.53
	100.17

Sample sent by G. A. Kennedy, 1256 S. Third street, Louisville.

Analysis No. 43.

Sio$_2$	94.90
Fe_2O_3	.56
Al_2O_3	2.84
CaO	none
MgO	.40
Alkalies	traces
Ignition	1.15

This sand is pure enough for making green glass.

McCRACKEN COUNTY.

Sample sent by the Paducah Pottery Co., Paducah.

Analysis No. 44.

SiO_2	98.86
Fe_2O_3	.40
Al_2O_3	.54
CaO	tr
MgO	tr

GREENUP COUNTY.

Sandstone labeled Hearth Sandstone, New Hampshire Furnace, Greenup Co., Ky.

Analysis No. 45.

SiO_2	94.855
Fe_2O_3, Al_2O_3	2.775
$CaCO_3$	.197
$MgCO_3$	.337
K_2O	.164
Na_2O	.047
Moisture and ignition	1.125
	100.00

BALLARD COUNTY.

Impure sand from T. D. Campbell, southern part of Ballard County.

Analysis No. 46.

A dirty olive brownish sand, abundantly mixed with ocherous or ferruginous material, mottled with blackish, containing some ocherous sandy concretions. Digested with HCl it left nearly 98% of sand composed mostly of rounded grains of hyaline quartz, mixed with some very fine sand, and some few rounded pebbles of milky quartz of various sizes.

The HCl dissolved less than 2% Al_2O_3, Fe_2O_3, MnO_2 with traces of CaO, MgO, etc.

This sand would answer well for the manufacture of the common kinds of glass in extensive use, as well as for mixing with cement and mortar for building purposes.

HICKMAN COUNTY.

Sample collected by J. R. Procter. From Columbus, Hickman County, above the town.

Analysis No. 47.

A nearly white sand, made up mostly of small rounded grains of hyaline quartz colored very light purplish with iron oxide, and containing a few friable concretions made by infiltration of carbonate of lime.

Washed and dried it left 99.40% of nearly pure white sand. It is no doubt pure enough for the manufacture of any but the very finest kind of glass.

GREENUP COUNTY.

Sandstone under main coal at Raccoon Furnace, Greenup County. Analysis No. 48.

SiO_2	97.30
Fe_2O_3, Al_2O_3	.53
CaO	.07
MgO	.25
K_2O	tr
Moisture and ignition	1.55
	100.00

FULTON COUNTY.

Sample from Chickasaw Bluff, 8 miles south of Hickman. Analysis No. 49.

SiO_2	96.060
Fe_2O_3, Al_2O_3, MnO_2	3.129
$CaCO_3$	.380
MgO	.173
P_2O_5	.051
H_2SO_4	.981
K_2O	.230
Na_2O	.124
H_2O and loss	1.600
	100.728

These siliceous deposits do not contain enough mineral fertilizing ingredients to make them valuable for application to the soil, nor enough alumina to make them good plastic clay. Yet they may be made useful in tempering clay which contains too much alumina or for the formation of common glass and for scouring purposes. Some of them are plastic enough to enable them to be molded and the siliceous material is fine enough in some to permit them to be used as bath brick for household scouring. Some could be used for common brick and some for fire brick.

CRITTENDEN OR LIVINGSTON COUNTY.

Sample sent by Pope Mining Company of Louisville either from Crittenden or Livingston County.
Analysis No. 50.

SiO_2	96.84
Fe_2O_3	.64
Al_2O_3	1.50
CaO	tr
MgO	tr
TiO_2	00.72
Moisture	.09
Ignition	1.03

CALLOWAY COUNTY.

Fine micaceous sand. Cretaceous sand two miles N. E. of New Concord.

Analysis No. 51.

A very fine grained white sand containing minute specks of mica. This sand all passes thru the coarse sieve.

SiO_2	98.145

WEBSTER COUNTY.

Sand sent by Shenall and Quirey of Wheatcroft, from the old Thomas place adjoining the town of Wheatcroft.

Analysis No. 52.

SiO_2	95.02
Fe_2O_3	.40
Al_2O_3	2.27
CaO	trace
MgO	trace
K_2O	.77
Na_3O	.47
TiO_2	trace
Ignition	.81

ROWAN COUNTY.

Sandstone from Rowan County Freestone Company, Farmers, Ky.

Analysis No. 53.

SiO_2	83.54
Fe_2O_3, Al_2O_3 etc.	9.86
CaO	1.01
MgO	trace
K_2O	1.32
Na_2O	.36
TiO_2	----------
Moisture	----------
Ignition	3.20

WOLFE COUNTY.

Gray sandstone streaked with black, rather fine grained. Sent by L. D. Mitchell of Torrent, Wolfe County, Ky.

Analysis No. 54.

SiO_2	95.76
Fe_2O_3	1.60
Al_2O_3	1.50
CaO	trace
MgO	trace
K_2O	----------
Na_2O	----------
TiO_2	----------
Moisture	----------
Ignition	1.36

UNION COUNTY.

Sandstone brought from Caseyville, Ky.

Analysis No. 55

Composition, dried at 212° F.

Sand and insoluble silicates	98.080
Alumina, and oxides of iron and Mn	.440
Lime	a trace
Magnesia	.466
Phosphoric acid	a trace
Sulphuric acid	.066
Potash	.328
Soda	.255
Water, expelled at a red heat	.600
	100.235

Quite a refractory sandstone; well suited for hearth-stones.

Sandstone brought from Caseyville, Kentucky.

Analysis No. 56.

Composition, dried at 212° F.

Sand and insoluble silicates	94.080
Alumina and oxides of iron and Mn	2.660
Lime	trace
Magnesia	.733
Phosphoric acid	.092
Sulphuric acid	.097
Potash	.250
Soda	.103
Water expelled at red heat	1.700
Loss	.285
	100.000

CRITTENDEN COUNTY.

Sandstone found two miles from Crittenden Furnace. Analysis No. 57.

	Best	Second Quality
Sand and insoluble silicates	99.080	98.680
Al and oxide of iron and Mn	.080	.380
Lime	trace	trace
Magnesia	.360	.400
Phosphoric acid	trace	trace
Sulphuric acid	.063	trace
Potash	.386	.464
Soda	.121	.058
Water expelled at a red heat	.300	.500
	100.390	100.482

Analysis 58

Laboratory No. G-3691. Glass sand, received from J. B. Hoeing, June 7, 1915. Sample was about 4 lbs. of nearly white, friable, fine-grained sandstone. Collected near Marion, Crittenden county, Ky. In preparing the sample some superficial iron stain was rejected.

Ferric oxid	.07
Silica	98.36
Calcium	trace

(Analysis by McHargue and Pfanstiel.)

STATE OF ILLINOIS

Analysis of washed sand from Ottawa, Illinois, as given by L. P. Foreman, Arnold, Pa.

Analysis No. 59.

Silica, SiO_2	99.64
Ferric oxide, Fe_2O_3	.05
Alumina, Al_2O_3	.11
Lime, CaO	.02
Ignition loss	.18
	100.00

STATE OF PENNSYLVANIA.

Analysis of consolidated glass sand, Derry, Pa., as given by R. M. Speer, Secretary of the American Window Glass Company, Pittsburg, Pa.

Analysis No. 60.

Silica, SiO_2	98.72
Ferric oxide, Fe_2O_3	.48
Alumina, Al_2O_3	.25
Manganese oxide	tr
Lime, CaO	.12
Magnesia, MgO	.07
Titanic acid, TiO_2	.07
Ignition loss	.27
	99.98

Analysis of glass sand produced by the Bridgeton Sand Company, Bridgeton, Pa.

Analysis No. 61.

Silica, SiO_2	99.25
Ferric oxide, Fe_2O_3	.03
Alumina, Al_2O_3	.51
Lime, CaO	.01
Magnesia, MgO	.12
Ignition loss	.08
Moisture	.02
	100.02

STATE OF WEST VIRGINIA.

Analysis of the No. 1 glass sand of the Berkeley Springs Sand Company, Berkeley Springs, West Virginia, made in the Survey laboratory.

Analysis No. 62.

Silica, SiO_2	99.580
Ferric oxide, Fe_2O_3	0.068
Alumina, Al_2O_3	0.199
	99.847

CHAPTER XVIII.

ANALYSES OF LIMESTONES SUITABLE FOR A FLUX IN MAKING GLASS.

The object in presenting the analyses of a few limestones in this terse chapter is to show that the State of Kentucky has within its borders a supply of the second great requisite in the glass making industry, viz.: limestone, which is everywhere used in some form in the manufacture of glass. Furthermore, should the interest of manufacturers be aroused to the point of establishing a glass factory in Kentucky, they may be guided somewhat in the selection of their fluxing limestone.

CARTER COUNTY.

Analysis No. 1. LAWTON.

The compact limestone of Lawton, Carter County, Kentucky, is evidently suitable for fluxing the glass sands of Kentucky and elsewhere. The chemist of the Libby-Owens Glass Company, Toledo, Ohio, has carefully tested this limestone for magnesium carbonate, and found none. The analysis is as follows:

Silica, SiO_2	2.72
Ferric oxide, Fe_2O_3	tr
Alumina, Al_2O_3	1.00
Calcium carbonate, $CaCO_3$	96.28
	100.00

It would appear from the above analysis that the alumina was determined by difference.

ROCKCASTLE COUNTY.

Analysis No. 2. MT. VERNON.

Analysis of the white oolitic limestone from the Kruger lime quarry just south of the depot at Mt. Vernon:

Moisture	.02
Ignition, CO_2	43.50
Silica, SiO_2	.52
Alumina, Al_2O_3	.16
Ferric oxide, Fe_2O_3	.08
Ferrous oxide, FeO	.07
Lime, CaO	55.19
Magnesia, MgO	.38
Titanium oxide, TiO_2	----------
Phosphorus pentoxide, P_2O_5	.05
Sulphuric anhydride, SO_3	.01
Strontia, SrO	tr
	99.98

The calcium carbonate equals	98.55
The magnesium carbonate equals	.79

The analysis was made by J. S. McHargue.

The limestone is the St. Genevieve.

The thickness of the bed is 17 feet and 2 inches.

FAYETTE COUNTY.

TATE CREEK.

Analysis No. 3.

Analysis of a sample of birds-eye limestone from Tate Creek, collected by Prof. A. M. Miller:

Silica, SiO_2, and silicates	2.60
Lime, CaO	53.18
Magnesia, MgO	.96
Ferric oxide, Fe_2O_3, etc.	.32

The above analysis would give $CaCO_3$	94.96
$MgCO_3$	2.02
Fe_2O_3, etc.	.32
SiO_2	2.60
	99.90

MERCER COUNTY.

MUNDAY'S LANDING.

Analysis No. 4.

Analysis of pulverized calcite from the Chinn Mineral Company with plant at Munday's Landing:

Moisture	.01
Ignition, CO_2	44.01
Silica, SiO_2	.10
Alumina, Al_2O_3	....
Ferric oxide, Fe_2O_3	.11
Lime, CaO	55.43
Magnesia, MgO	.77
Sulphuric anhydride, SO_3	....
	100.43

The above analysis would give calcium carbonate as 98.82, and the magnesium carbonate as 1.61. The analysis was made by J. S. McHargue.

Analysis No. 5.

Laboratory No. G-3966. Powdered calcite from Chinn Mineral Company, Mundy's Landing, Mercer county, Ky. Collected July 31, 1920, by C. H. Richardson.

Sample, about 5 lbs. of the very fine, nearly white powder.

Analysis of the Air-dry Sample	Per cent.
Moisture	trace
Ignition	42.66
Silica, SiO_2	0.37
Alumina, Al_2O_3	0.16
Ferric oxid, Fe_2O_3	0.08
Calcium oxid, CaO	53.50
Magnesium oxid, MgO	0.74
Barium sulfate, $BaSO_4$	2.30
Total	99.81
Calcium carbonate, $CaCO_3$, equivalent to the CaO	95.49
Magnesium carbonate, $MgCO_3$, equivalent to the MgO	1.58

The iron is in the ferrous condition, as ferrous carbonate.

(Analysis by S. D. Averitt)

Analysis No. 6.

Laboratory No. G-3938.—Crushed calcite from the Chinn Mineral Company, Mundy's Landing, Mercer county, Ky. Collected July 31, 1920, by C. H. Richardson.

Sample, 14½ ozs. of milky calcite in small pieces. A little adhering limestone; a very little ZnS, some barite in streaks in the calcite and a 38 gram lump of barite equivalent to 7% of the sample.

Analysis of the Air-dried Sample.	Per cent.
Moisture	trace
Ignition	40.50
Silica, SiO_2	0.10
Alumina, Al_2O_3	0.14
Ferric oxid, Fe_2O_3	0.11
Calcium oxid, CaO	49.78
Magnesium oxid, MgO	0.65
Barium sulfate, $BaSO_4$	9.12
Total	100.40
$CaCO_3$ equivalent to the CaO	88.84
$MgCO_3$ equivalent to the MgO	1.39

Most of the iron is in the ferrous condition, as ferrous carbonate, in the sample.

(Analysis by S. D. Averitt)

CARTER COUNTY.

Analysis No. 7.

Laboratory No. G-3920.—Limestone from quarry at Tygart, Carter county, Ky. Collected by C. H. Richardson, July 13, 1920.

Sample, a 2-lb. lump of cartridge-buff colored, hard, fine-grained limestone of subconchoidal fracture. Contains a small streak of dark brown colored spar.

Analysis of the Air-dried Sample.	Per cent.
Moisture	trace
Ignition (carbon dioxid, etc.)	40.85
Silica, SiO_2	6.61
Alumina, Al_2O_3	0.07
Ferric oxid, Fe_2O_3	0.28
Calcium oxid, CaO	51.48
Magnesium oxid, MgO	0.58
Total	99.87
Calcium carbonate, $CaCO_3$, equivalent to the CaO	91.88
Magnesium carbonate, $MgCO_3$, equivalent to the MgO	1.24

Most of the iron is in the ferrous condition, as ferrous carbonate, in the sample.

(Analysis by S. D. Averitt)

Analysis No. 8.

Laboratory No. G-3573.—Nearly white limestone labeled "No. 4, Atlas Stone Co., Olive Hill, Carter county, Ky." Sample, a single lump, received from J. B. Hoeing, Feb. 10, 1914.

Analysis of the Air-dried Sample.	Per cent.
Moisture and ignition (Carbon dioxid, etc.)	43.82
Silica, SiO_2	0.38
Alumina, Al_2O_3	0.66
Ferric oxid, Fe_2O_3	0.24
Calcium oxid, CaO	54.06
Magnesium oxid, MgO	0.70
Total	99.86
Calcium carbonate equivalent to the CaO	96.48
Magnesium carbonate equivalent to the MgO	1.47

(Analysis by J. S. McHargue)

STATE OF INDIANA.

Analysis No. 9.

Analysis of the oolitic limestone of Bedford, Indiana, which is so widely used as a fluxing lime in the glass sand industry of West Virginia is as follows:

Silica, SiO_2, and moisture	.68
Ferric oxide and alumina, Fe_2O_3, Al_2O_3	.15
Calcium carbonate, $CaCO_3$	98.27
Magnesium carbonate, $MgCO_3$	.84
	99.90

STATE OF WEST VIRGINIA.

Analysis No. 10.

Analysis of the Martinsburg, West Virginia, limestone as furnished by the Standard Lime and Stone Company is as follows:

Silica, SiO_2	1.670
Iron oxide and alumina, Fe_2O_3, Al_2O_3	.876
Organic matter	.122
Total insoluble	2.668
Ferric oxide, Fe_2O_3	.138
Alumina, Al_2O_3	.522
Lime, CaO	52.948
Magnesia, MgO	1.245
Sulphur trioxide, SO_3	tr
Carbon dioxide, CO_2	42.625
Water, H_2O	.037
	100.00

CHAPTER XIX.

SUMMATION.

The chemical analyses of the sand and sandstones collected by the author in the field study in the preparation of this report group themselves into four classes, as follows:

1. Excellent glass sands from which all types of glass can be successfully manufactured.
2. Glass sands of fair quality which require washing and screening.
3. Glass sands which can be produced by washing and screening, but which are excellent building sands.
4. Sandstones that pulverize to a fairly white, fine grained sand, but which are too rich in alumina for the best glass.

(1) This group includes the Olive Hill District, the Leitchfield-Tygart District, and the Western Kentucky District.

These sands appear to be the equal of the best glass sands of America. They are therefore strongly recommended. It must be remembered that all of these sands have been analyzed as unwashed sands, and, therefore, as washing removes a large amount of the iron and alumina from the sand, these two factors would run much lower in a washed sample and the silica correspondingly higher. Yet the silica content of the unwashed samples is approximately 99 per cent.

(2) The second group includes all of the sands of the Big Sandy Valley. The analyses are of unwashed river sands that contain a certain amount of coal grains. The percentage of silica has been determined without burning out the coal. If the coal which would be burned out in the batch was burned out before the analysis was made the silica content would be much higher even tho the ash of the burned coal remained in the sample. By the careful washing and screening of this sand a much higher grade of glass sand can be produced than the analyses imply.

(3) This group embraces all of the Ohio River sands from Paducah to Catlettsburg. From them by careful washing and screening glass sands can be obtained and the courser material used in the manufacture of cement and concrete.

(4) This group includes all of the yellowish white micaceous sandstones of the Homewood formation and the bluish gray sandstones that underlie it and which have been used so extensively for building purposes. These are found around Farmers and in the valley of the Big Sandy.

The sands in group 1 can be quarried, crushed, washed, screened, and delivered F. O. B. for prices ranging from $2.00 to $2.50 per ton. The freight rates to the borders of adjacent states would be around $1.00 per ton. The freight rate from Ottawa, Illinois, to Louisville is given as $2.50 per ton, and the freight rate from Berkeley Springs, West Virginia, to Charleston, West Virginia, as $4.50 to $5.00.

It would therefore appear that the Olive Hill glass sand should find a ready market in western West Virginia; that the Leitchfield-Tip Top sands should be used in Louisville; and that the sands around Marion and Princeton should be locally used in the manufacture of glass, and shipped into the states bordering Kentucky on the north.

Kentucky is exceedingly fortunate:

(1) In possessing an inexhaustible supply of most excellent glass sand either for the manufacture of glass within the state or for shipment to other states.

(2) In containing within her borders limestones and calcite of high degree of purity to be used as a flux in the treatment of the sands.

(3) In possessing an abundance of natural gas which is the ideal fuel in the glass industry, coal from which producer gas can be manufactured, and petroleum which is often used as a fuel.

(4) In having fluorspar in abundance which is equal in purity to any spar in America and which is required in the manufacture of certain kinds of glass.

R. W. Stone, Geologist of the United States Geological Survey, has kindly furnished the author with the following data:

From 1905 to 1908 there were three or more producers and the figures for those years have been published. Beginning with 1909 there were no less than three producers and, in order to avoid revealing confidential information, the production of glass sand in Kentucky has been combined in the published reports with that of other states. This explains the reason why the figures for the past eleven years are lumped.

Glass sand produced in Kentucky, 1905-1919.

	Short tons	Value
1905	739	$480
1906	2,400	2,040
1907	7,400	4,592
1908	5,990	4,283
1909		
1910		
1911		
1912		
1913		
1914	79,374	117,940
1915		
1916		
1917		
1918		
1919		
Total	95,903	$129,335

CHAPTER XX.

BIBLIOGRAPHY.

This bibliography has been carefully compiled thru work done in the library of the Carnegie Institute of Technology at Pittsburg, Pa., the city and state libraries at Charleston, W. Va., the city and university libraries at Lexington and Louisville, and the Kentucky Geological Survey and State libraries at Frankfort, Ky., and many smaller libraries in which special articles have been found. While it is not a complete bibliography, it is believed that it lists the more important publications dealing with glass sands and the glass sand industry. Most of the publications cited have been read by the author in the preparation of this report.

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FINIS

INDEX.

Alphabetical Arrangement of Subject Matter and Authors.